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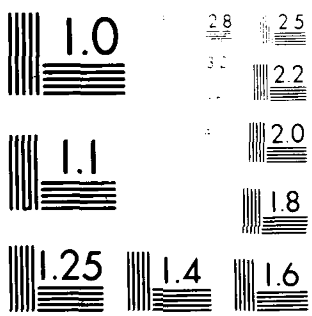
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ADVANCED TRENDING ANALYSIS/EDS DATA PROGRAM

McDonnell Aircraft Company
McDonnell Douglas Corporation
P.O. Box 516
St. Louis, Missouri 63166

January 1982

Final Report for Period: May 1979 - September 1981

Approved for public release; distribution unlimited

Aero Propulsion Laboratory
Air Force Wright Aeronautical Laboratories
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio 45433

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This technical report has been reviewed and is approved for publication.

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GTE Monitoring/Diagnostic Systems
GTE Health Trending
GTE Fault Detection/Isolation
GTE Maintenance Information Management
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Thermodynamic Cycle Monitoring (TCM)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Ground, flight, and maintenance data was collected during the F-15/F100 Engine Diagnostic System (EDS) Flight Evaluation and provided to the Air Force Aero-Propulsion Laboratory (AFWAL/POTC). This data was used by the Air Force, in a concurrent program, to verify a gas turbine engine fault detection/isolation and health trending algorithm employing gas path analysis. In addition, the EDS Flight Evaluation served as a demonstration vehicle for a prototype Maintenance Information Management System (MIMS). Independent assessments

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of the gas path analysis algorithm and of the prototype MIMS were performed and the results are presented. Several lessons learned about the automatic recording of in-flight trending data for high performance gas turbine engines in modern tactical aircraft are also presented.

FOREWORD

The work documented in this report was performed under Contract No. F33615-78-C-2070 for the Air Force Aero Propulsion Laboratory (AFWAL/POTC), Wright-Patterson Air Force Base. The Technical Monitor for the Air Force was Mr. Charles A. Skira. The McDonnell Aircraft Company (MCAIR) Program Manager was Mr. John W. Steurer. Mr. David C. Perryman was the MCAIR Study Manager and principal author of this report. Preparation of this report was directed by Ms. Patricia A. Penn.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

SECTION I

INTRODUCTION

The Advanced Trend Analysis Program (MCAIR Contract No. F33615-78-C-2070) provided the Air Force Aero Propulsion Laboratory (AFWAL/POTC) with ground, flight, and maintenance data collected during the F-15/F100 Engine Diagnostic System (EDS) Flight Evaluation. This data was used by the Air Force in a concurrent program contracted to Systems Control Technology, Inc. (SCT). In this concurrent program, the Turbine Engine Fault Detection and Isolation (TEFDI) Program, SCT was to use the Advanced Trend Analysis Program data to verify their gas turbine engine fault detection/isolation and health trending algorithm which employs gas path analysis. Also, SCT was to use the EDS Flight evaluation as a demonstration vehicle for their prototype Maintenance Information Management System (MIMS). In addition to supplying the EDS data to the Air Force, MCAIR was to provide an independent assessment of SCT's algorithm and prototype MIMS as part of the Advanced Trend Analysis Program. For reasons documented in this report, these assessments yielded inconclusive results. However, several lessons were learned about the automatic recording of in-flight trending data for gas turbine engines installed in tactical aircraft like the F100 in the F-15.

The cooperation and support of both Mr. C. Skira, the AFWAL/POTC Program Technical Monitor, and Dr. Ron De Hoff, the SCT TEFDI Program Manager, in the completion of this effort is gratefully acknowledged.

SECTION II

DATA ACQUISITION

The Advanced Trend Analysis Program was structured to use specific data acquired by the F-15/F100 EDS Program to develop/verify a turbine engine fault detection/isolation and trending algorithm based on gas path analysis. The data was obtained on a non-interference basis from a data bank of EDS recorded ground/in-flight data and EDS aircraft/engine maintenance records established during the EDS Flight Evaluation. The following sections provide background information on the EDS recorded data, the maintenance record data, and the Flight Evalution during which this data was obtained.

1. EDS RECORDED DATA - The Advanced Trend Analysis Program employed selected EDS recorded parameters. Since only these parameters were available, a thorough understanding of the EDS acquisition system was required. The following paragraphs describe the EDS data flow network, the EDS parameters selected for use in this program, detailed information about these parameters, and the logic that determines when to record them.

a. EDS Data Flow - The EDS data flow network consists of several important elements. This network is shown schematically in Figure 1 for both installed and uninstalled operation. Engine sensor signals are input to each engine mounted Engine Multiplexer Unit (EMUX) for preliminary processing and digitization. During installed operation, EMUX data goes to the airframe mounted Data Processor Unit (DPU), along with data from the aircraft Air Data Computer (ADC) and left/right engine fuel flowmeters, for additional processing and storage. Critical go/no go information from the EMUX's and DPU is supplied to the EDS Status Panel, located near the left wheel well, and to the EDS Advisory Lights, located in the cockpit. Data stored in the DPU is then transferred to the Diagnostic Display Unit (DDU) either directly or via the Data Collection Unit (DCU). During uninstalled operation, the DDU takes the place of the DPU. Then EMUX data, along with data from the M-37 test stand instrumentation, goes directly to the DDU. Once in DDU memory, the data is transferred to the Auxiliary Ground Processor (AGP) for final processing and mass storage. The EDS data collection process and hardware are shown schematically in Figure 2.

All on-board EDS data processing and recording is performed by the two engine mounted EMUX's (left and right) and the airframe mounted DPU. A detailed schematic, showing data flow through the left hand EMUX and the DPU, is given in Figure 3. The EMUX performs the analog-to-digital conversions of all the engine sensor signals except vibration, provides a thermocouple cold junction reference signal, performs some preliminary data conditioning and processing, serializes the digitized sensor signals for transmission to the DPU, and stores engine and individual module serial numbers. Additional signals, both analog and digital, from the aircraft ADC go directly to the DPU as do the analog output signals from the left/right engine fuel flowmeters. The DPU performs additional data processing, filters and digitizes the engine vibration signals, continuously updates engine time and cycle data and stores all data in temporary registers, detects engine events, and transfers selected data, depending on the event detected, from the temporary registers

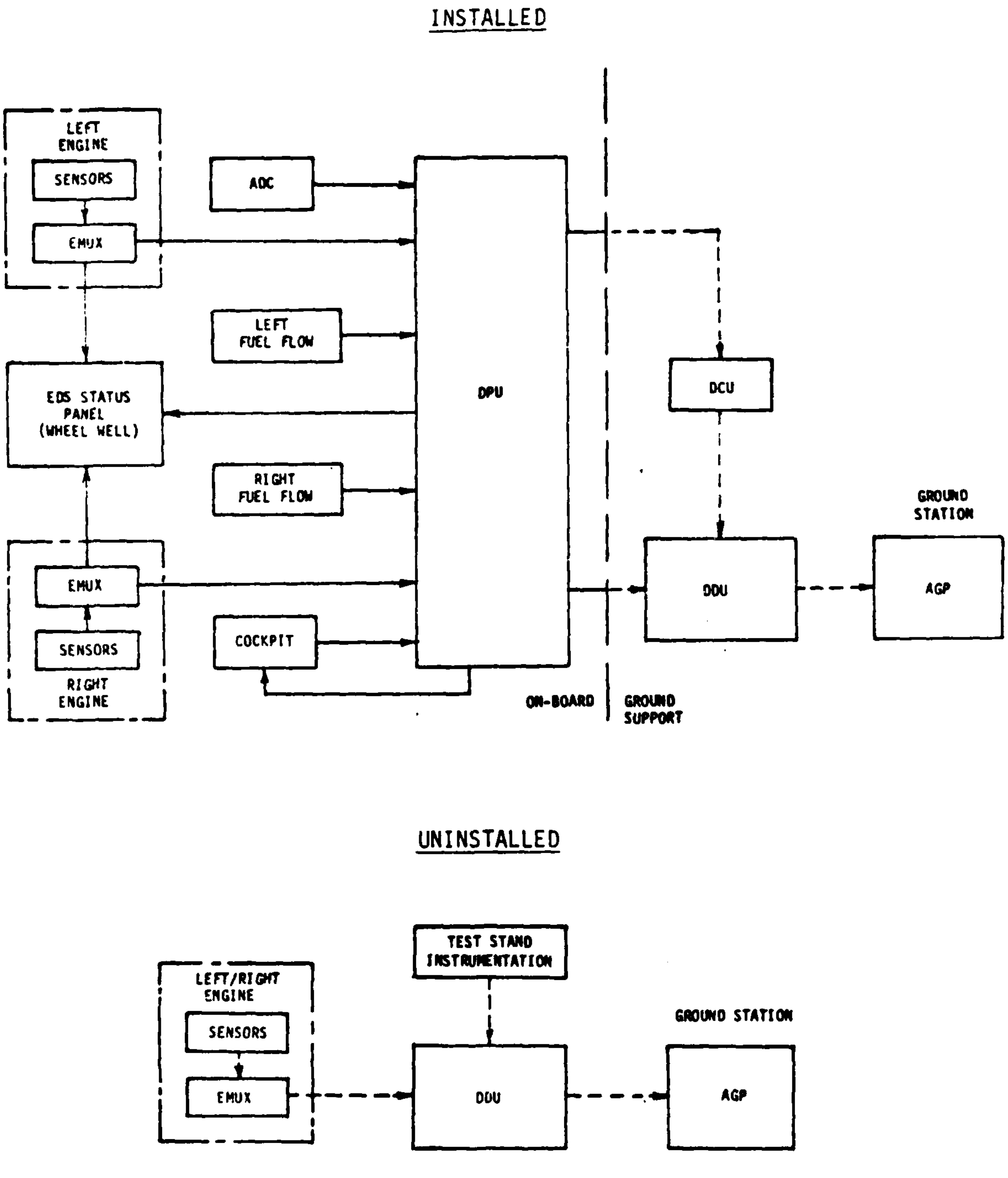


Figure 1. F100 EDS Data Flow Schematic

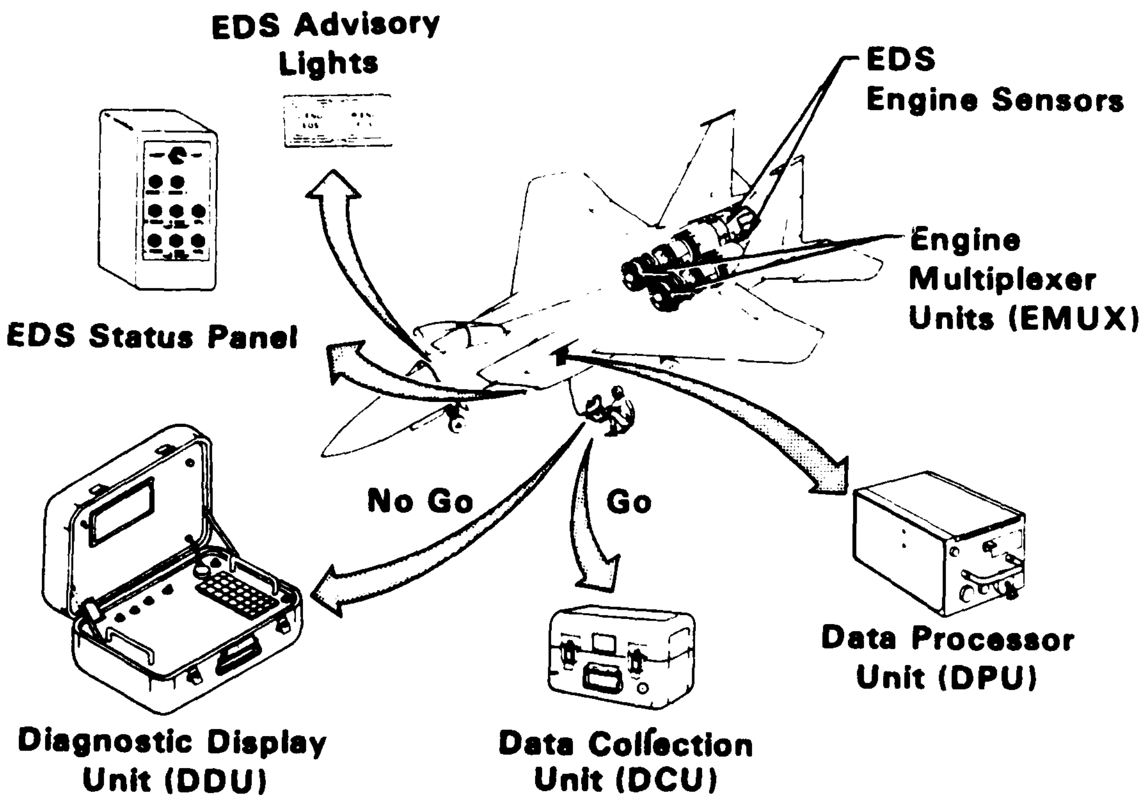


Figure 2. EDS Data Collection

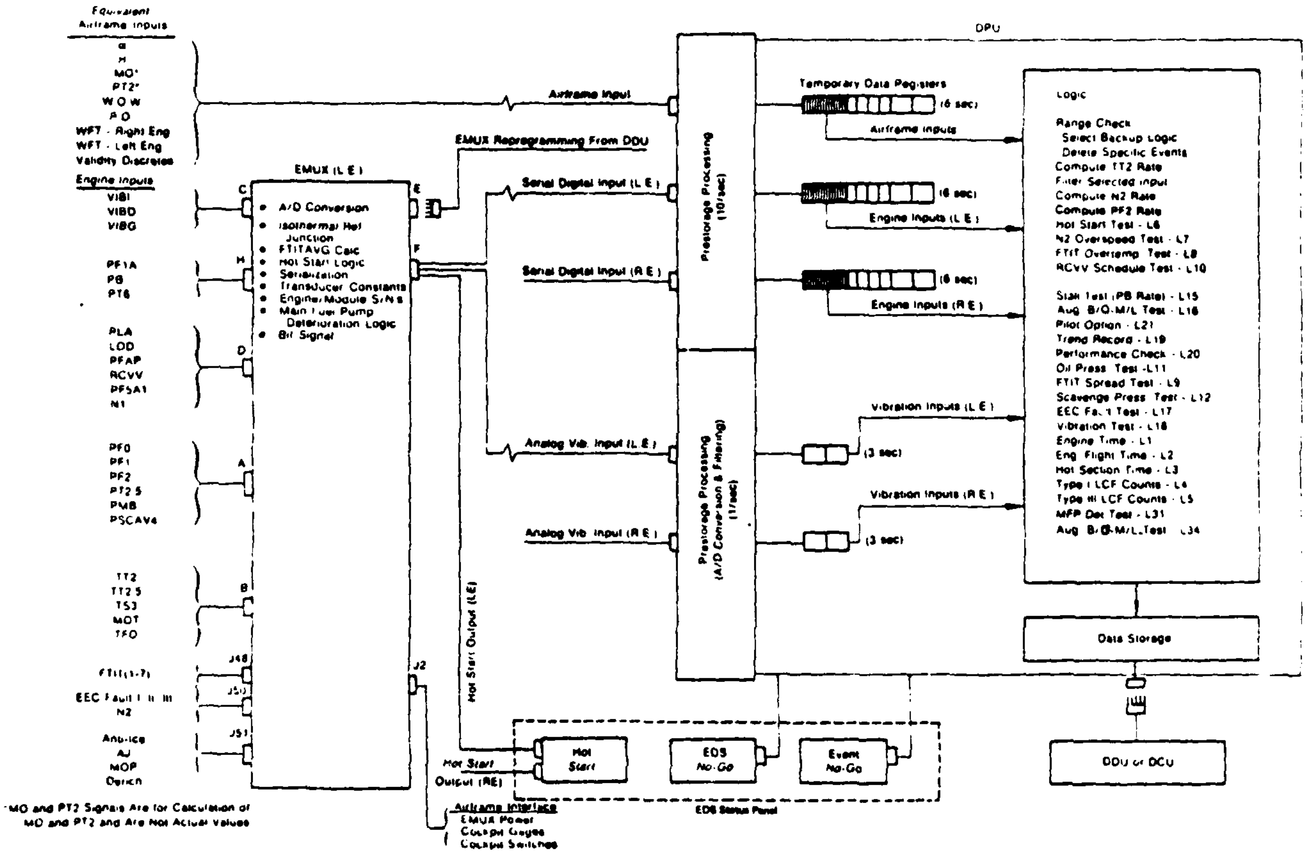


Figure 3. F100 EDS Data Flow

to event data storage. A complete list of the engine events and automatic data records that the DPU is programmed to detect and store is given in Table 1. Originally, only the data recorded during two of these records, the Trend and Performance Check records, was to be used by the Advanced Trend Analysis Program. These two records automatically store data during stable engine operation. This stable engine operating data is required by the fault detection/isolation and trending algorithm to obtain satisfactory results. Late in the EDS Flight Evaluation, the Pilot Option record logic was modified to provide an Automatic Takeoff record to supplement the stabilized Trend and Performance Check data with quasi-stabilized data. The Trend, Performance Check, and Automatic Takeoff record logic will be discussed in Section II.1.d.

The DDU is used to collect and temporarily store data, to diagnose and troubleshoot engine faults, to facilitate engine trim, and to display data for an operating engine in "real-time". Each use represents a different DDU operational mode. Event data in DPU storage is transferred to DDU bulk memory either directly or via the DCU. This DDU bulk memory can store data from as many as 5 typical aircraft flights each consisting of 2 to 3 events per engine. The DDU contains diagnostic and troubleshooting logic, consistent with applicable Air Force Technical Orders, which uses event data, stored in bulk memory, to isolate engine faults. Engine trim is performed with the DDU either connected to the DPU, for installed trim, or to the EMUX, for uninstalled trim. During trim, the DDU supplies simulated inputs to the engine controls, senses ambient temperature and pressure, displays the trim band limits and current value of the trim parameter, and provides instructions on adjustments required to bring the trim parameter within limits. Both installed and uninstalled "real-time" data display can be accomplished with the DDU connected to either the DPU, for the installed case, or to the EMUX, for the uninstalled case. For the installed case, the DPU transfers to the DDU, in "real-time", the data it receives from either the left or right engine EMUX as selected by the DDU operator. During installed trims or "real-time" operation, the DPU continues to monitor both engines for event occurances and stores the event data for subsequent, non "real-time", transfer to the DDU. For the uninstalled case, EMUX data is transferred directly to the DDU. The DDU provides a "real-time" display of the data, monitors the engine for event occurances, and stores event data in a dedicated event data storage area separate from the DDU bulk memory. This stored event data is automatically transferred to the bulk memory upon engine shutdown.

The DDU event detection logic is similar, but not identical, to the DPU event detection logic. The DDU is not programmed to store Trend, Performance Check, or Pilot Option (Automatic Takeoff) records (events 14, 15, and 16 in Table 1). However, the DDU does have equivalent logic for two of these three DPU records; the DDU Average record, in place of the DPU Trend record, and the DDU Discrete record, in place of the DPU Pilot Option record. Only the DDU Average record, being equivalent to the DPU Trend record, is relevant to the Advanced Trend Analysis Program. A DDU Average record is not taken automatically but must be commanded from the DDU keyboard by the DDU operator. The Trend, Performance Check, and Automatic Takeoff record logic, in the DPU, and the Average record logic, in the DDU, are discussed in detail in Section II.1.d.

Event data storage capacity is limited in both the DPU and DDU. DPU event data storage is limited to at most one occurance of each event, per

TABLE 1. EDS DETECTED EVENTS/STORED RECORDS

EVENT NUMBER	EVENT
1	Hot Start
2	N2 Overspeed
3	FTIT Overtemp
4	FTIT Spread
5	RCVV Out-Of-Limits
6	MOP Out-of-Limits, Priority 2*
7	MOP Out-of-Limits, Pirority 1**
8	No. 4 Bearing Oil Scavenge Pressure Out-Of-Limits
9	Engine Stall
10	EEC Fault
11	Inlet Vibration Out-of-Limits
12	Difuser Vibration Out-of-Limits
13	Gearbox Vibration Out-of-Limits
14	Trend Record
15	Performance Check Record
16	Pilot Option Record***
17	Main Fuel Pump Deterioration
18	Augmentor Blowout/Mislight

* MOP Too High
** MOP Too Low
*** Modified To Provide Automatic Takeoff Record Late In The Flight Evaluation.

engine. In the case of multiple detection of the same event, data for only one occurance of that event will be stored before the memory is cleared after a data transfer. Since stored data can be transferred from the DPU only after a flight or after engine shutdown, for installed ground operation, data for at most one occurance of each event, per engine, is available for post-flight or post-run analysis. For most of the Flight Evaluation, Trend and Performance Check records were continuously overwritten in memory as they occurred such that only the last occurance was available. However, late in the evaluation, the overwrite logic for both of these records was modified to store a new record only if the engine had been stabilized for a longer period of time that it had been for the currently stored record. For all other events, except the Automatic Takeoff record, only the first occurance is available. The Automatic Takeoff record was added late in the evaluation and was implemented such that one record, encompassing both engines, was stored per DPU transfer unless a Pilot Option record was manually requested. In this event, the Automatic Takeoff record was overwritten and lost. In the DDU, "real-time" event data storage is also limited to at most one occurance of each event with the exception of the manually commanded Average and Discrete records. Up to four Average records and up to five Discrete records can be stored during an uninstalled engine run. If more than these maximum number of records are commanded, only the last four Average and the last five Discrete records are available for post-run analysis. For all other DDU events, the first, and only the first, occurance is available for post-run analysis.

Following transferral of the data from the DDU, final processing and transferral to mass storage was accomplished by the AGP. A Harris Slash 6-1 Computer, Figure 4, served as the AGP for the EDS Flight Evaluation. Data flow within the AGP is shown in Figure 5. The work file, consisting of the raw data, is written onto disk storage from the DDU. The Data Reduction Program (DRP) screens the raw data in this file for erroneous entries, computes values for the various EDS parameters, and writes these values to disk storage. To obtain values for the EDS parameters, the raw data has to be re-formatted with specific bytes of the data combined to obtain intermediate results. Some of these intermediate results require conversion from integer counts to real values while others require conversion from integer counts to equivalent Engineering Unit values. All of these values are written to the Indexed Sequential File (ISF) data base and, for a Trend, Performance Check or DDU Average record, selected values are written to the Turbine Engine Performance Analyzer (TEPA) input file. The ISF is a keyed file which allows selective access of data records by engine serial number, aircraft tail number, flight date, etc. TEPA is a computer program developed by Pratt and Whitney Aircraft to detect and isolate faults, either failed sensors or degraded components, in turbine engines.

The ISF data base was transferred from disk storage to magnetic tape storage on a regular basis. The magnetic tape created during this data transfer was a direct archive copy of the ISF disk. As such, this tape contained, in addition to the data, organizational information about the ISF generated by the Harris Operating System. The detailed information needed to interpret this tape is considered proprietary by Harris. Because of this, another magnetic tape was created periodically for transmittal to St. Louis. This additional tape was a sequential copy of the ISF and contained the data in the same sequential order as the ISF. The Langley/St. Louis/WPAFB data link began with the transmittal of this sequential tape to St. Louis, see Section III.

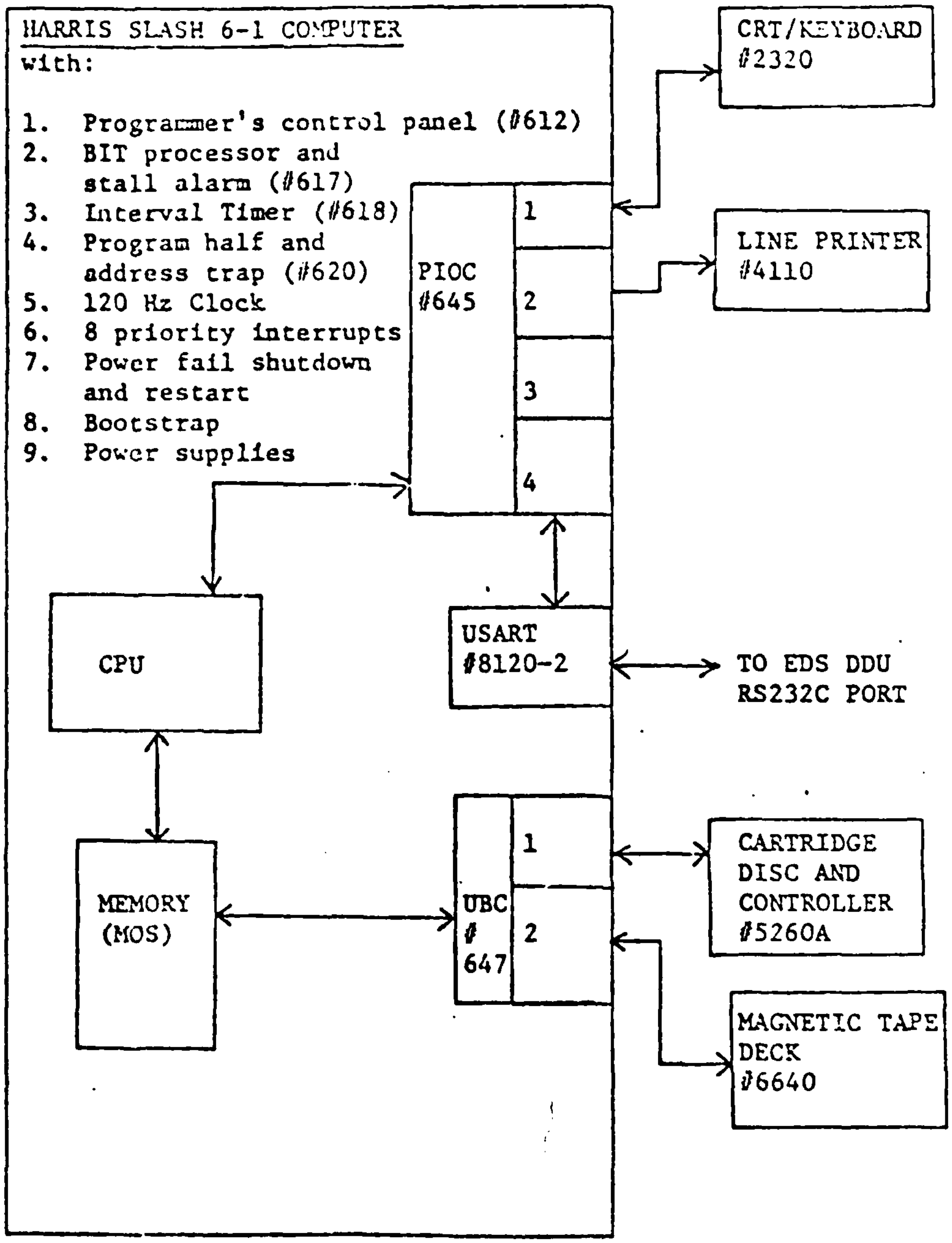


Figure 4. EDS Auxiliary Ground Processor

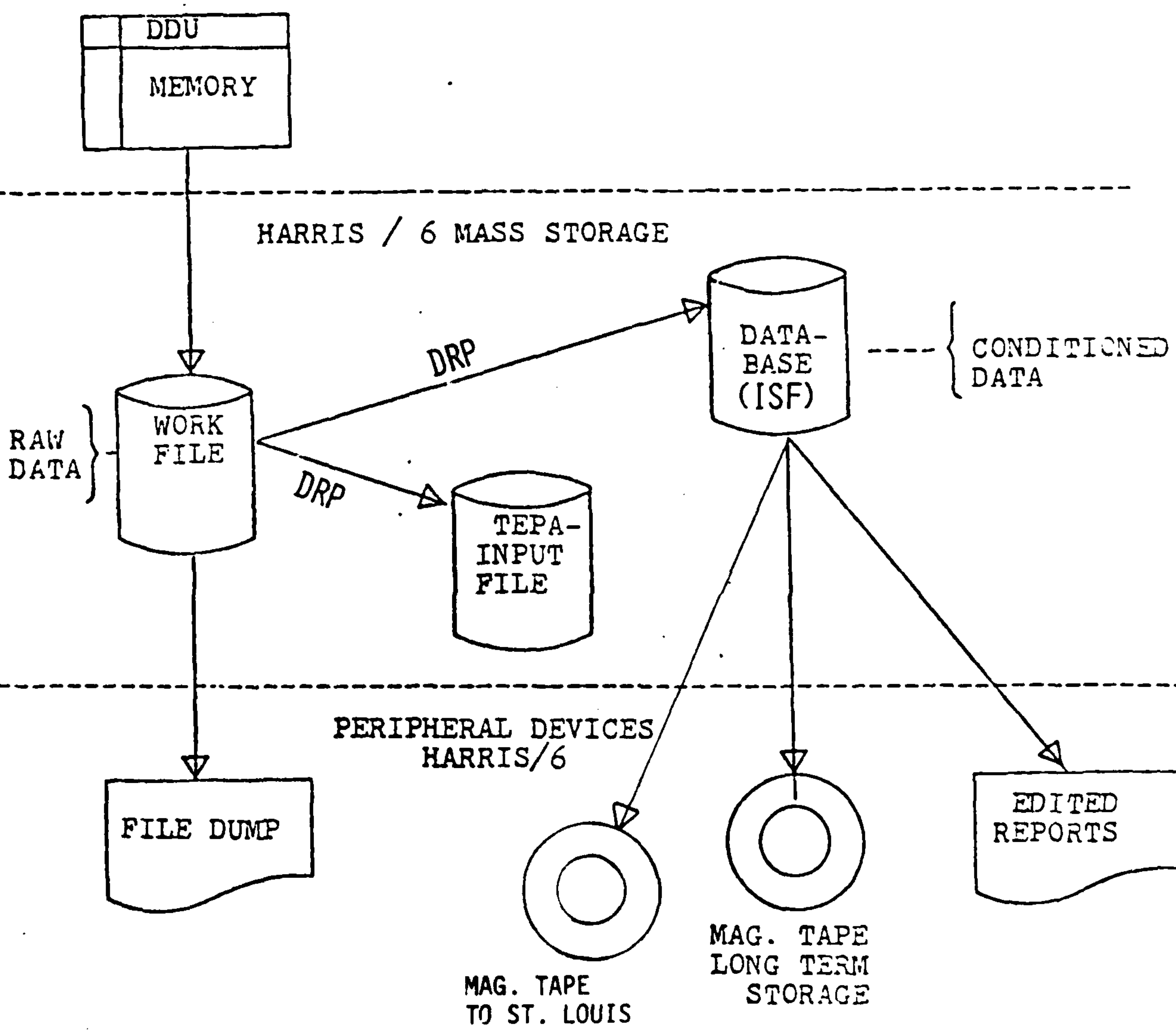


Figure 5. AGP Data Flow

b. Parameter List - Sixty-three of the EDS parameters recorded during a DPU Trend, Performance Check, or Automatic Takeoff-record, or a DDU Average Data Record were used for the Advanced Trend Analysis Program. These parameters, listed in Figure 7, are grouped into the following six categories:

- o Gas Path Parameters
- o Data Collection/Documentation Parameters
- o Engine Life/Usage Parameters
- o Engine Build Parameters
- o Engine Vibration Parameters
- o Diagnostic/Troubleshooting Parameters

This parameter list was coordinated with, and approved by, the USAF and SCT and is consistent with the data requirements established by SCT during Phase I of the Turbine Engine Fault Detection and Isolation (TEFDI) Program.

There were four basic types of EDS parameters; scan, update, automatic and configurational. These types are defined as follows:

Scan Parameters - These are the sampled EDS parameters made up of the digitized engine/airframe sensor and discrete signals. Scan parameter values in the DPU/DDU temporary storage registers are updated at the nominal rate of 10 per second and are processed by the DPU/DDU logic routines. When an engine event is detected, selected scan parameter values are transferred from the temporary registers to permanent storage.

Update Parameters - These parameters are computed/derived from the scan parameters by the DPU/DDU. Existing values in permanent storage are updated as new values become available.

Automatic Parameters - These parameters are automatically generated and appended to data records by the DDU.

Configurational Parameters - These parameters are manually entered into DPU/EMUX storage to document the system configuration. They are manually updated as configuration changes are made.

The type of each of the Advanced Trend Analysis Program parameters is given in Table 2.

In addition to the parameters discussed above, the data transferred to WPAFB will also include 18 EDS event detection flags. The format and a description of these flags is given in Section III.2.

c. Detailed Parameter Information - Detailed information about the Advanced Trend Analysis Program parameters has been compiled. This information, presented in Appendix A, includes the type of sensor used to measure the parameter, the type and extent of compensation required by the sensor, and an accuracy analysis for the parameter. The accuracy analysis includes the overall system accuracy as well as the basic sensor, EMUX, and DPU/DDU accuracies which are root-sum-squared to compute the system accuracy. Accuracy data for some of the remaining, non-gas path, parameters is also summarized in Appendix A. Parameters not discussed in this appendix are

TABLE 2. ADVANCED TREND ANALYSIS/EDS DATA PROGRAM PARAMETER LIST

Gas Path Parameters

Symbol	Description	Type
H	Altitude	Scan
MO	Mach Number	Scan
TT2	Engine Inlet Temperature	Scan
PT2	Engine Inlet Pressure	Scan
N1	Low Spool Rotor Speed	Scan
N2	High Spool Rotor Speed	Scan
TT2.5	Fan Exit Duct Temperature	Scan
PT2.5	Fan Exit Duct Pressure	Scan
TS3	Compressor Exit Skin Temperature	Scan
WFT	Total Fuel Flow	Scan
PB	Burner Pressure	Scan
FTITAVG	Average Fan Turbine Inlet Temperature	Scan
PT6	Augmentor Inlet Pressure	Scan
AJ	Exhaust Nozzle Throat Area	Scan
RCVV	Rear Compressor Variable Vane Angle	Scan
PLA	Power Lever Angle	Scan
FTIT 1-7	Individual Fan Turbine Inlet Temperature (Seven Parmeters)	Scan

Data Collection/Documentation Parameters

Symbol	Description	Type
ACFTN	Aircraft Tail Number	Configurational
ENGSN	Engine Serial Number	Configurational
FLTNO	Flight Number	Update
SYSTM	Time of Data Record	Scan
RECDT	Date of Data Record	N/A
DDUTM	Time of Data Collection	Automatic
DDUDT	Date of Data Collection	Automatic
STABTM**	Stabilization Time	Update

Engine Life/Usage Parameters

Symbol	Description	Type
ENGOT	Total Engine Operating Time	Update
ENGFT	Total Engine Flight Time	Update
HS1TM	Hot Section 1 Time	Update
HS2TM	Hot Section 2 Time	Update
HS3TM	Hot Section 3 Time	Update
LC1CT	Type I LCF Count	Update
LC3CT	Type III LCF Count	Update

TABLE 2 (Concluded). ADVANCED TREND ANALYSIS/EDS DATA PROGRAM PARAMETER LIST

Engine Build Parameters

Symbol	Description	Type
FANSN	Inlet/Fan Module Serial Number	Configurational
CORSN	Core Module Serial Number	Configurational
HITSN	High Turbine Serial Number	Configurational
LOTSN	Fan Drive Turbine Serial Number	Configurational
AUGSN	Augmentor Module Serial Number	Configurational

Engine Vibration Parameters

Symbol	Description	Type
VIBI	Inlet Case Vibration, Overall	Scan*
VIBD	Diffuser Case Vibration, Overall	Scan*
VIBG	Gearbox Case Vibration, Overall	Scan*
VIBI1	Inlet Case Vibration, N1 Narrowband	Scan*
VIBI2	Inlet Case Vibration, N2 Narrowband	Scan*
VIBD1	Diffuser Case Vibration, N1 Narrowband	Scan*
VIBD2	Diffuser Case Vibration, N2 Narrowband	Scan*
VIBGP	Gearbox Case Vibration, PTO Narrowband	Scan*

Diagnostic/Troubleshooting Parameters

Symbol	Description	Type
LVI	EEC Level I Fault	Scan
LVII	EEC Level II Fault	Scan
LVIII	EEC Level III Fault	Scan
MFPDT	Main Fuel Pump Deterioration Signal	Scan
MOT	Main Oil Temperature	Scan
MOP	Main Oil Pressure	Scan
MPB	Main Breather Pressure	Scan
PSCV4	No. 4 Bearing Scavenge Pressure	Scan
TFO	Fuel Inlet Temperature	Scan
PFO	Fuel Inlet Pressure	Scan
PF1	Fuel Pump Boost Pressure	Scan
PF2	Fuel Pump Discharge Pressure	Scan
PF1A	Augmentor Fuel Pump Discharge Pressure	Scan
ANTIC**	Anti-Ice Discrete Signal	Scan

*NOTE: The Three Vibration Signals From Either Engine (inlet case, diffuser case, and gearbox case) Are Sampled in 6 Second Cycles With Each Signal Being Digitized and Processed As A Scan Parameter (Updated 10 Times Per Second) During Its 2 Second Portion Of The Cycle.

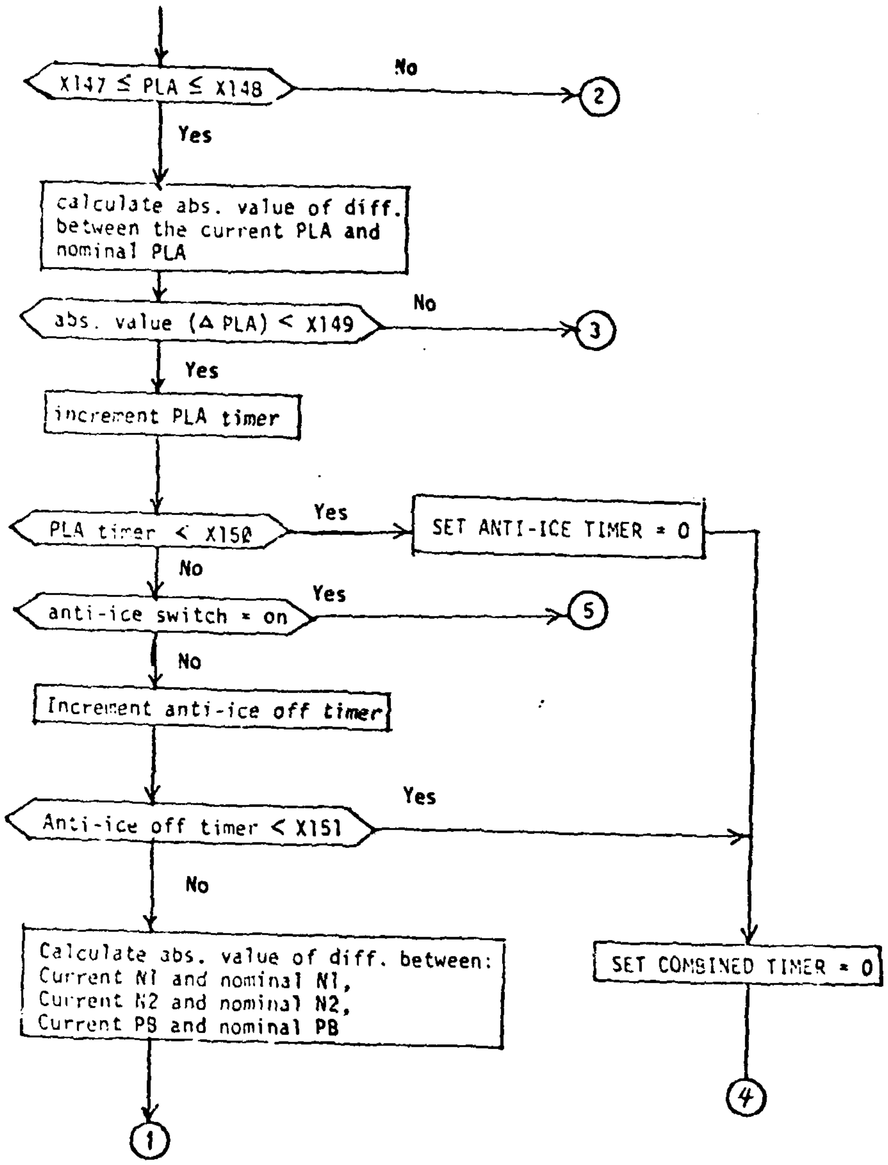
**Parameters Substituted For Original Parameters; See Section III.2.

either discrete parameters, whose accuracy is undefined, or parameters like time and cycle data, where reasonable but not precise accuracy is adequate.

d. Record Logic - Two functions of the DPU are to detect specific events and then to record selected data, dependent on the event detected in permanent storage. During uninstalled operation, engine events are detected by the DDU. There are a total of 18 such engine events that the DPU is programmed to detect and 17 that the DDU is programmed to detect. Four of these events, or records, were used by the Advanced Trend Analysis Program. The DPU Trend, Performance Check, and Automatic Takeoff records and the DDU Average record.

The primary objective of the DPU Trend and Performance Check record logic and of the DDU Average record logic is to assure stable engine operation prior to recording data. The stability requirement should be as stringent as possible without being so restrictive that data is never or rarely recorded. To accomplish this, the engine stability requirements, as well as most of the other parameters that define the data record window, are implemented in the logic as re-programmable constants. In this way, the window parameters, including the stabilization requirements, could be altered during the course of the Flight Evaluation as deemed necessary or desireable. In fact, several changes to the values of these re-programmable constants were made over the course of the Flight Evaluation to deal with trending data acquisition problems that were experienced. In addition to changing the values of these constants, a quasi-stabilized data record, the Automatic Takeoff record, was added to the EDS to supplement the three original stabilized data records. The trending data acquisition problems experienced during the Flight Evaluation are discussed in detail in Section II.3.b. Three changes were made to the Trend and Performance Check record software during the Flight Evaluation. The original software is denoted as Software Configuration No. 1 and the three modified versions as Software Configuration Numbers 2 through 4. The Trend and Performance Check record logic and the values of the associated re-programmable constants for Software Configuration Number 1 are given in Figures 6 and 7 and in Table 3. Software Configuration Numbers 2 and 3 consisted of the same Trend and Performance Check record logic as Configuration Number 1 but with the re-programmable constant changes shown in Table 4. Note that Configuration No. 2 consisted of an increase in the Trend record minimum PLA limit (X147), while Configuration No. 3 consisted of an additional increase in this limit as well as a significant reduction in both the Trend and Performance Check record stabilization requirements (X150, X151, and X162). Software Configuration No. 4 did not make any additional changes in the re-programmable constants associated with Configuration No. 3. However, both the Trend and Performance Check record logic blocks were modified to add a stabilization timer and to store only the Trend and Performance Check record with the longest stabilization time. The Configuration No. 4 Trend and Performance Check logic and the added re-programmable constants are shown in Figures 8 and 9 and Table 5. Note that in Figure 8, the Trend record logic schematic has been greatly simplified from that given in Figure 6 to facilitate showing the modification associated with Configuration No. 4.

The DDU Average record remained unchanged during the Flight Evaluation. The Average record logic and the values of its associated re-programmable constants are given in Figure 10 and Table 6. The DDU Average record is activated from the DDU keyboard by the DDU operator as shown in Figure 11. It should be noted that, before a DDU Average record is taken, it must be



COMPUTE FREQUENCY = 2/SEC

Figure 6. Trend Record Logic
Software Configuration No. 1

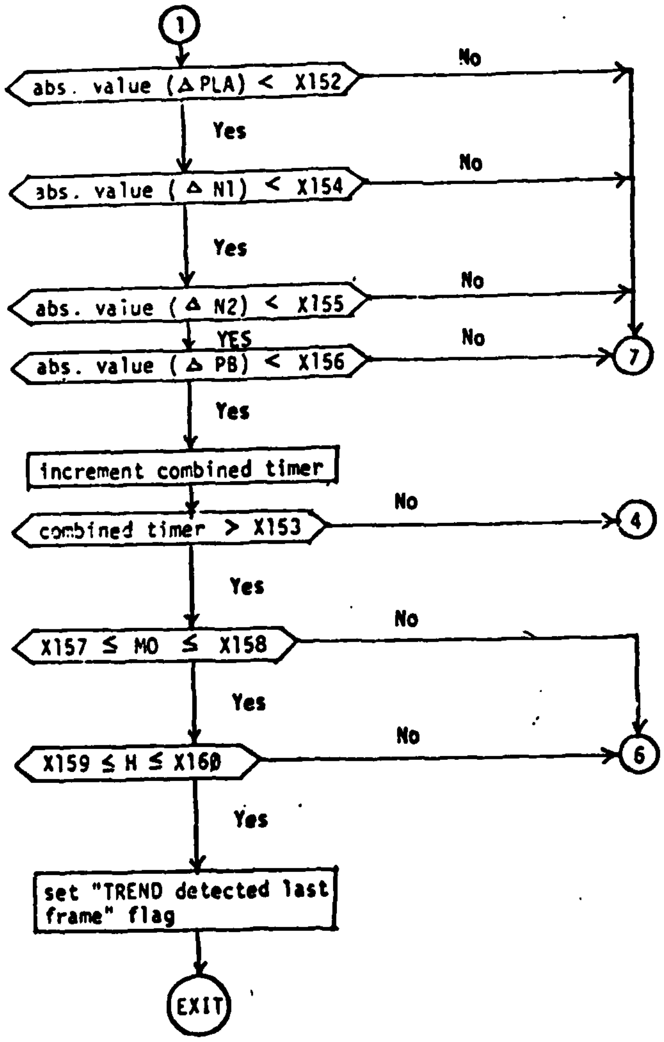


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Figure 6 (Continued). Trend Record Logic
Software Configuration No. 1

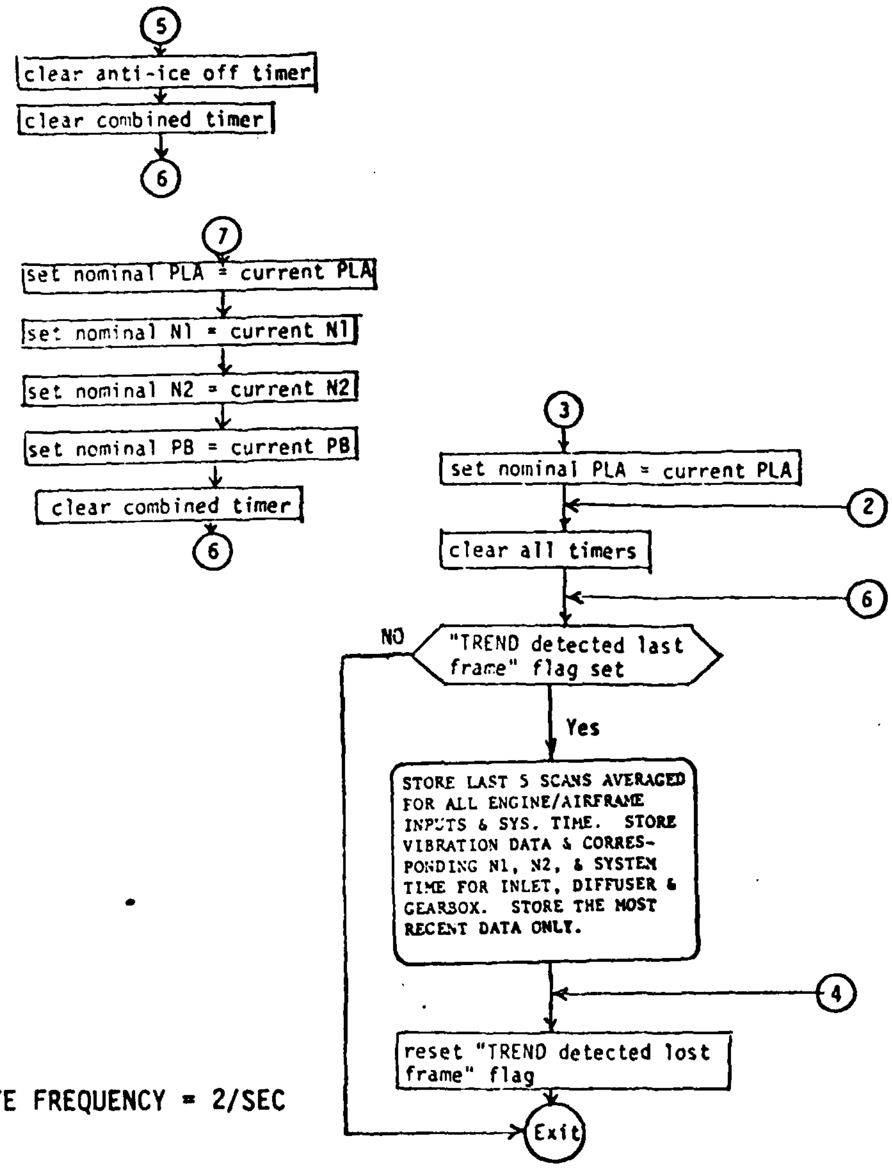

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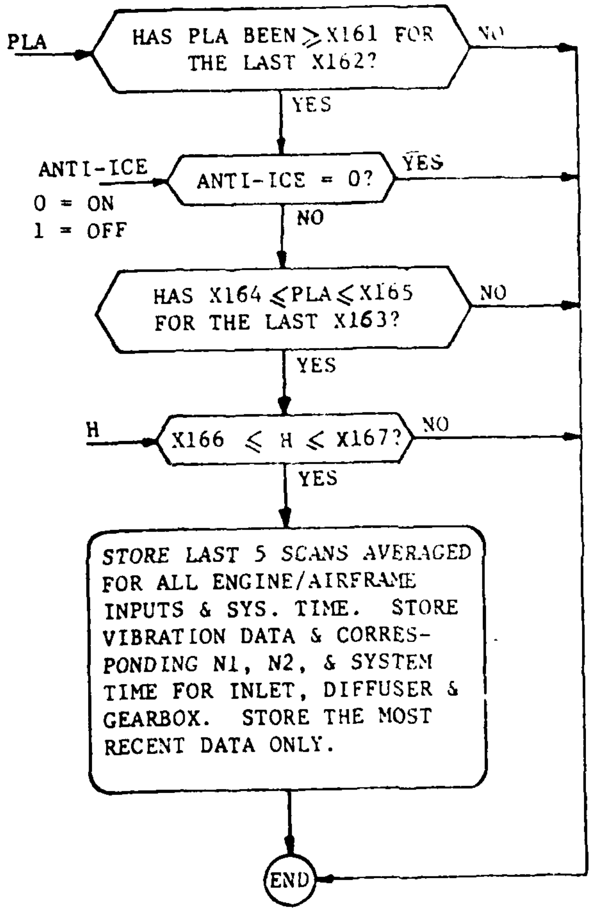
Figure 6 (Concluded). Trend Record Logic
Software Configuration No. 1



Compute Frequency = 10/Sec

Figure 7. Performance Check Record Logic
Software Configuration No. 1

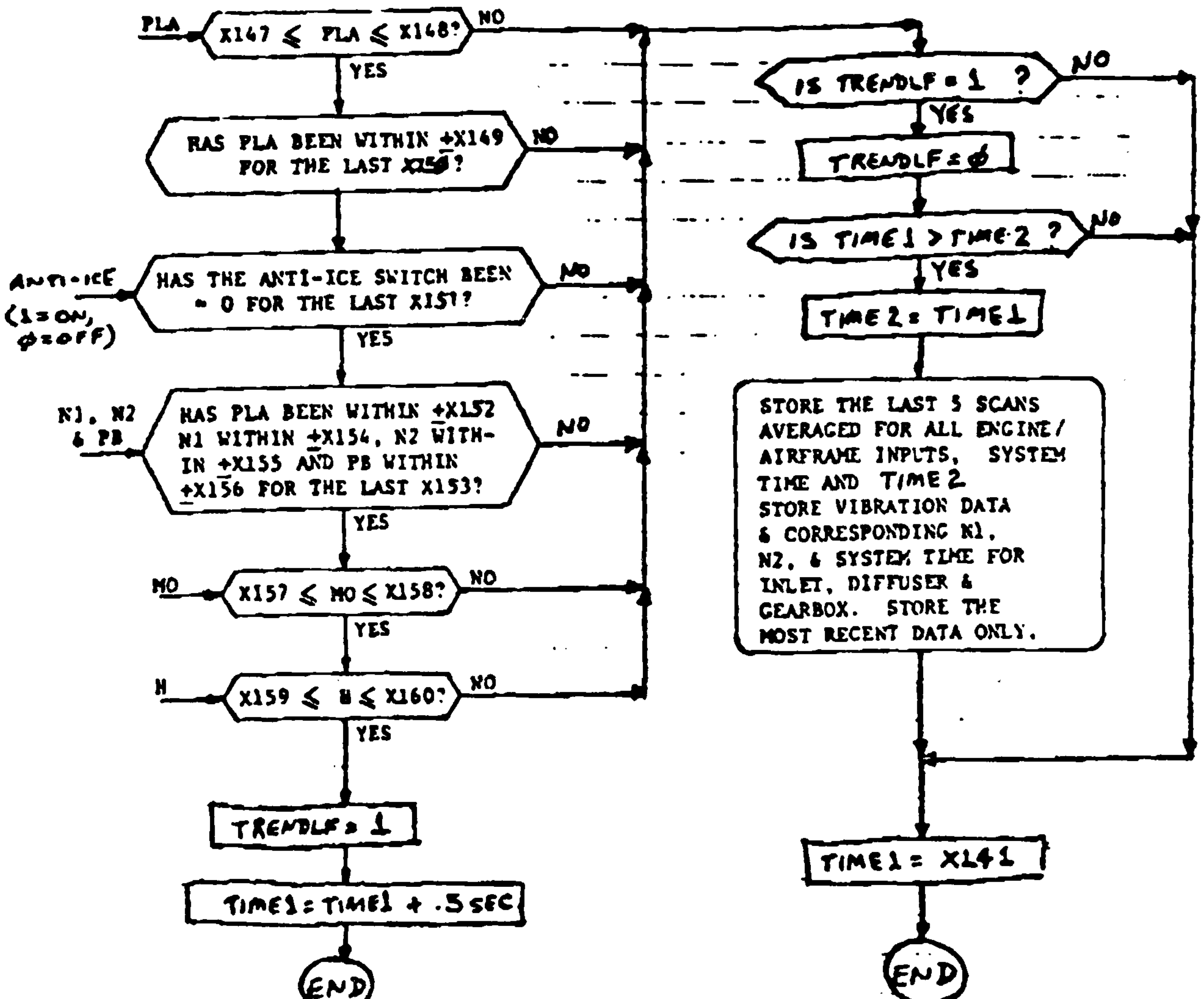
TABLE 3. VALUES OF CONSTANTS USED IN TREND/PERFORMANCE CHECK RECORD LOGIC
Software Configuration No. 1

CONSTANT	VALUE	DEFINITION
X147	30.0 Deg	PLA Limit - Trend Record
X148	88.0 Deg	PLA Limit - Trend Record
X149	10.0 Deg	PLA Range - Trend Record
X150	115.0 Sec	Time Constant - Trend Record
X151	60.0 Sec	Time Constant - Trend Record
X152	1.0 Deg	PLA Range - Trend Record
X153	5.0 Sec	Time Constant - Trend Record
X154	60.0 RPM	N1 Range - Trend Record
X155	60.0 RPM	N2 Range - Trend Record
X156	.005	PB Range - Trend Record
X157	0.0	Mach Limit - Trend Record
X158	0.7	Mach Limit - Trend Record
X159	0.0 Ft	Altitude Limit - Trend Record
X160	10,000.0 Ft	Altitude Limit - Trend Record
X161	83.0 Deg	PLA Limit - Performance Record
X162	150.0 Sec	Time Constant - Performance Record
X163	10.0 Sec	Time Constant - Performance Record
X164	83.0 Deg	PLA Limit - Performance Record
X165	88.0 Deg	PLA Limit - Performance Record
X166	8000.0 Ft	Altitude Limit - Performance Record
X167	25000.0 Ft	Altitude Limit - Performance Record

TABLE 4. TREND/PERFORMANCE CHECK SOFTWARE CONFIGURATION SUMMARY

CONFIGURATION NUMBER	X147	X150	X151	X162
1	30.0 Deg.	115.0 Sec.	60.0 Sec.	150.0 Sec.
2	45.0	↓	↓	↓
3	60.0	15.0	15.0	20.0

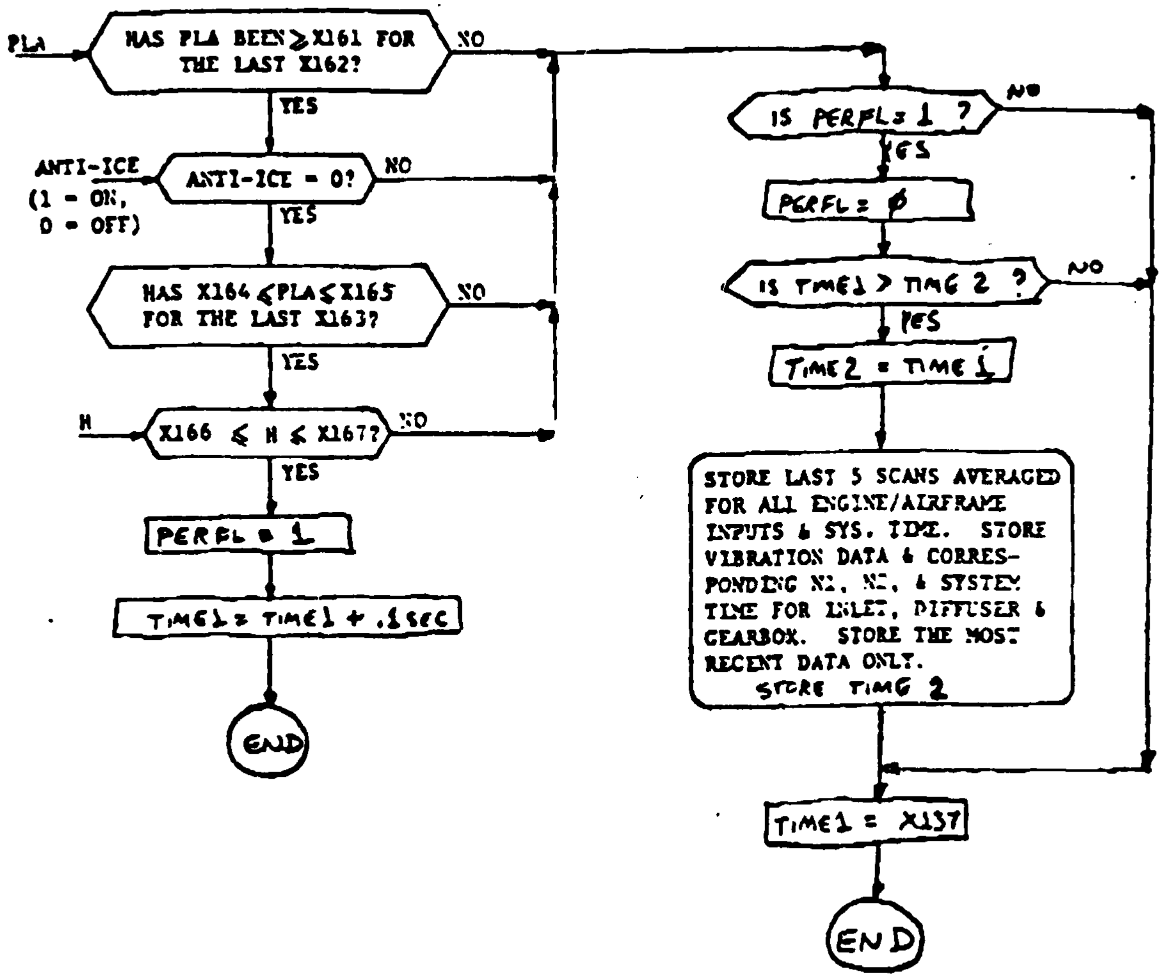
NOTE: All Other Constants Remained The Same As For Configuration Number 1 (See Table 3).



COMPUTE FREQUENCY = 2/SEC

INITIAL VALUES: TRENDLF = 0
TIME1 = 0
TIME2 = 0

Figure 8. Trend Record Logic
Software Configuration No. 4



COMPUTE FREQUENCY = 10/SEC
INITIAL VALUES: PERFL = 0
TIME1 = 0
TIME2 = 0

Figure 9. Performance Check Record Logic
Software Configuration No. 4

TABLE 5. ADDITIONAL RE-PROGRAMMABLE CONSTANTS
Software Configuration No. 4

CONSTANT	VALUE	DEFINITION
X137	30.0 Sec	Performance Check Record Time Constant
X141	35.0 Sec	Trend Record Time Constant

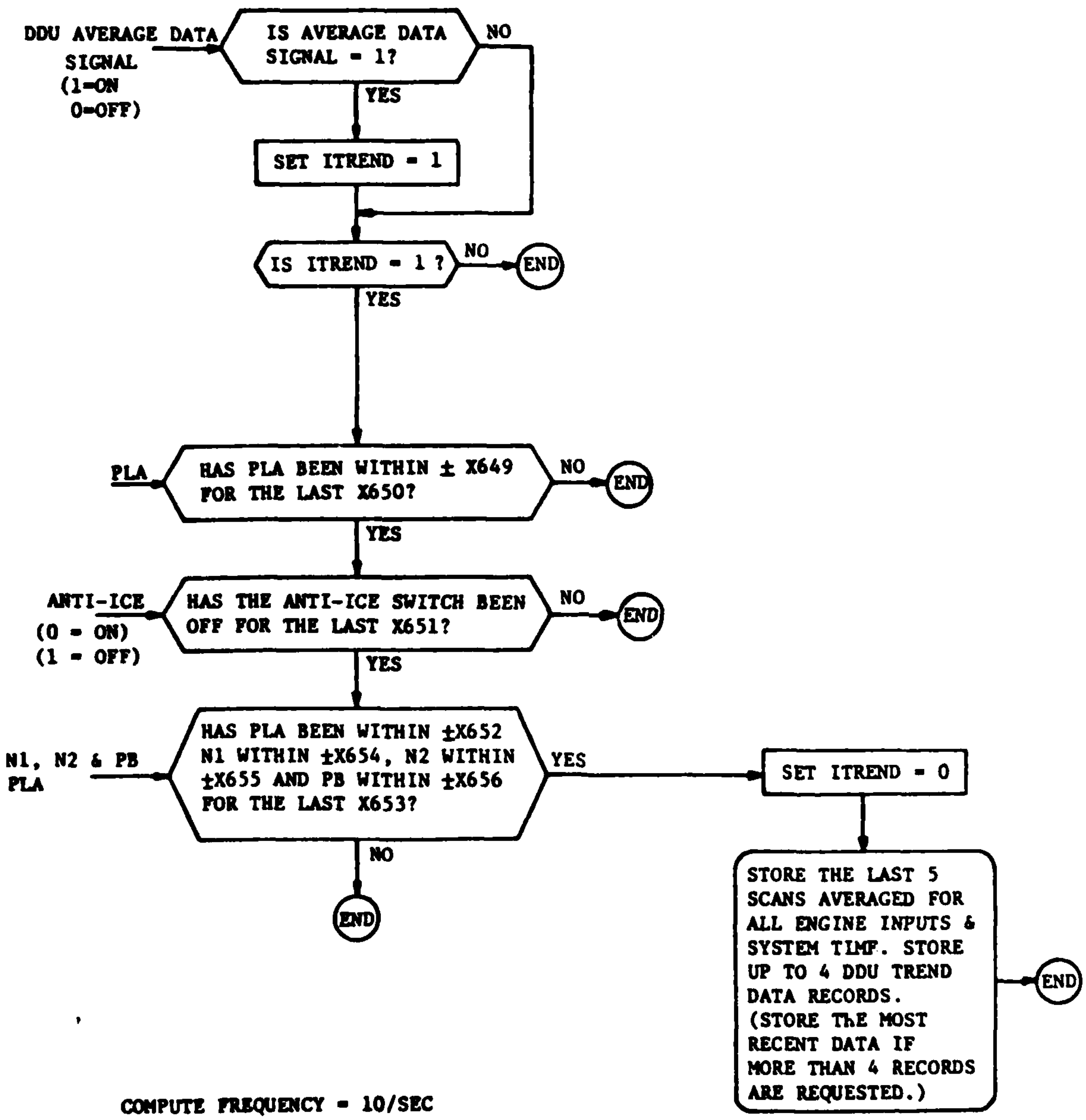


Figure 10. Average Data Record Logic

TABLE 6. VALUES OF CONSTANTS USED IN AVERAGE DATA RECORD LOGIC

CONSTANT	VALUE	DEFINITION
X649	10.0 Deg.	PLA Range-Average Record
X650	180.0 Sec.	Time Constant-Average Record
X651	65.0 Sec.	Time Constant-Average Record
X652	1.0 Deg.	PLA Range-Average Record
X653	5.0 Sec.	Time Constant-Average Record
X654	60.0 RPM	N1 Range-Average Record
X655	60.0 RPM	N2 Range-Average Record
X656	0.0025	PB Range-Average Record

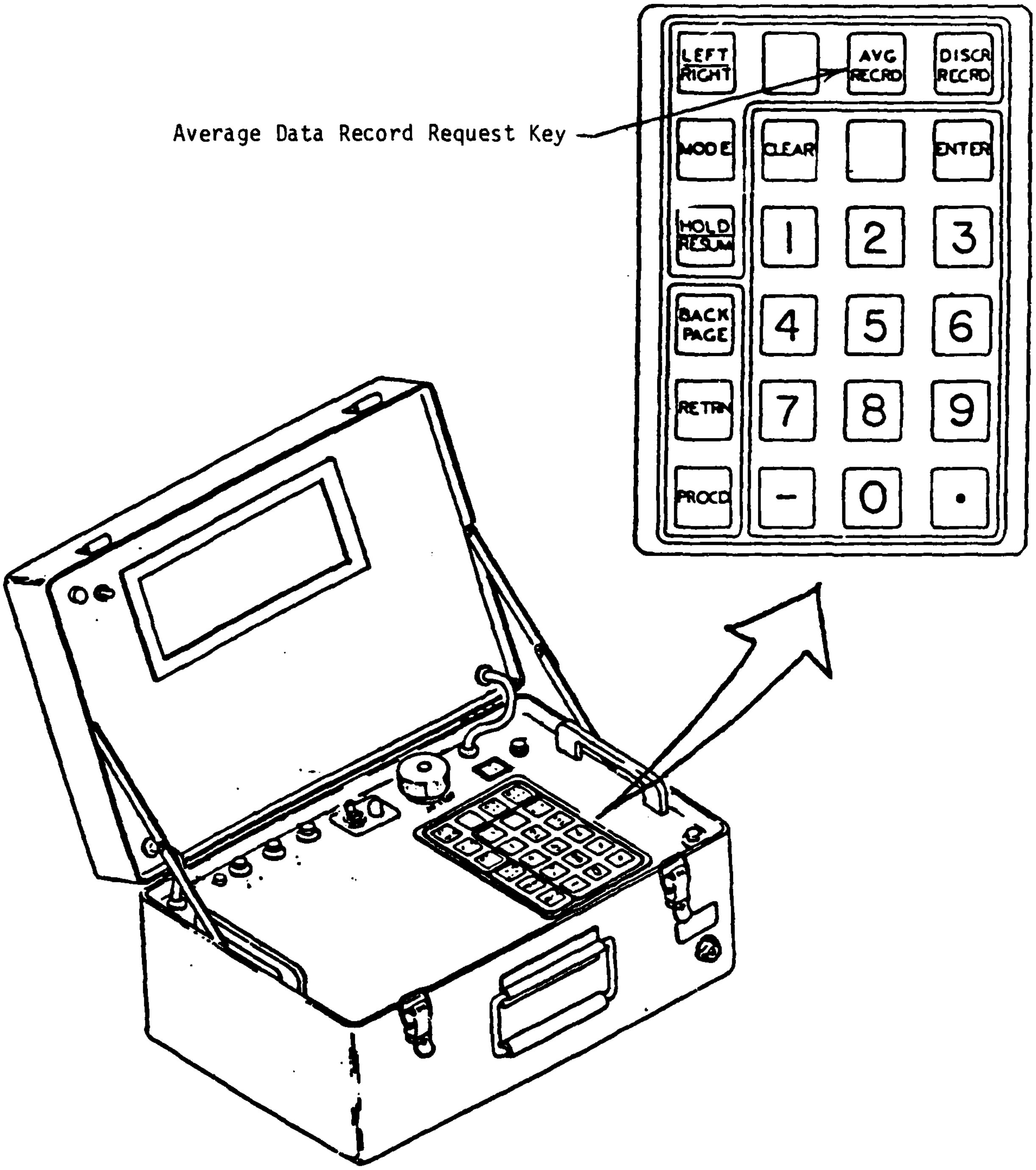


Figure 11. DDU Keyboard and Average Data Record Request Key

requested by the operator and the engine stability requirements must be satisfied.

The quasi-stabilized Automatic Takeoff record was added late in the Flight Evaluation to supplement the stabilized Trend and Performance Check records. This record automatically activates the Pilot Option record logic to store a time history of 18 data scans from 4.5 seconds before to 1 second after the weight-off-wheels point of a takeoff. The exact timing of these 18 scans is shown in Figure 12. Normally, there will be one stored Automatic Takeoff record, encompassing both engines, per DPU data transfer. However, if the pilot should manually request a Pilot Option record, this manual record will take precedence over the takeoff record and will be stored instead.

2. MAINTENANCE RECORDS - One of the primary objectives of the EDS Flight Evaluation was to determine the potential of the EDS to reduce engine maintenance time/manhours and, therefore, to increase aircraft operational readiness. Because of this, a detailed and complete record of aircraft/engine maintenance actions was kept throughout the Flight Evaluation. All of these maintenance records were made available, through the advanced Trend Analysis Program, to the USAF and SCT.

The AFM 66-1 Maintenance Data Collection System was the primary source for maintenance action documentation. The AFM 66-1 records consist of:

- AFTO From 781A, "Maintenance Discrepancy and Work Document,"
- AFTO Form 349, "Maintenance Data Collection Record,"
- AFTO Form 93, "Modular Engine Time and Cycle Accumulation Record,"
- AFTO 00-35D-54, "Removed Material Deficiency Report (MDR)."

In addition to these AFM 66-1 records, maintenance action documentation was also available from the following, EDS unique, records:

- Flight De-Brief Sheet (FDS),
- Flight Evaluation Sheet (FES).

The MCAIR EDS Office was the central collection point at Langley for all of these records. A complete description of the EDS Flight Evaluation maintenance data collection procedure is given in (References 1, 2, and 3).

Copies of the EDS maintenance records were mailed from Langley to St. Louis on a weekly basis. As part of the EDS Project, these records were processed and analyzed by MCAIR Maintainability/Reliability personnel. Hard-copy files of these records were established and the AFTO Form 349 data were entered into the MCAIR Automated EDS Maintenance Record File. Transmittal of these files to the USAF and SCT using the Advanced Trend Analysis Program Data Link will be discussed in Section III.

3. FLIGHT EVALUATION - The Advanced Trend Analysis Program employed data obtained during the EDS Flight Evaluation. This evaluation took place at Langley AFB, Virginia from April 1980 through the end of June 1981. During the course of the evaluation, several problems were experienced in the acquisition of the data records used by the Advanced Trend Analysis Program. However, these problems were solved late in the Flight Evaluation and

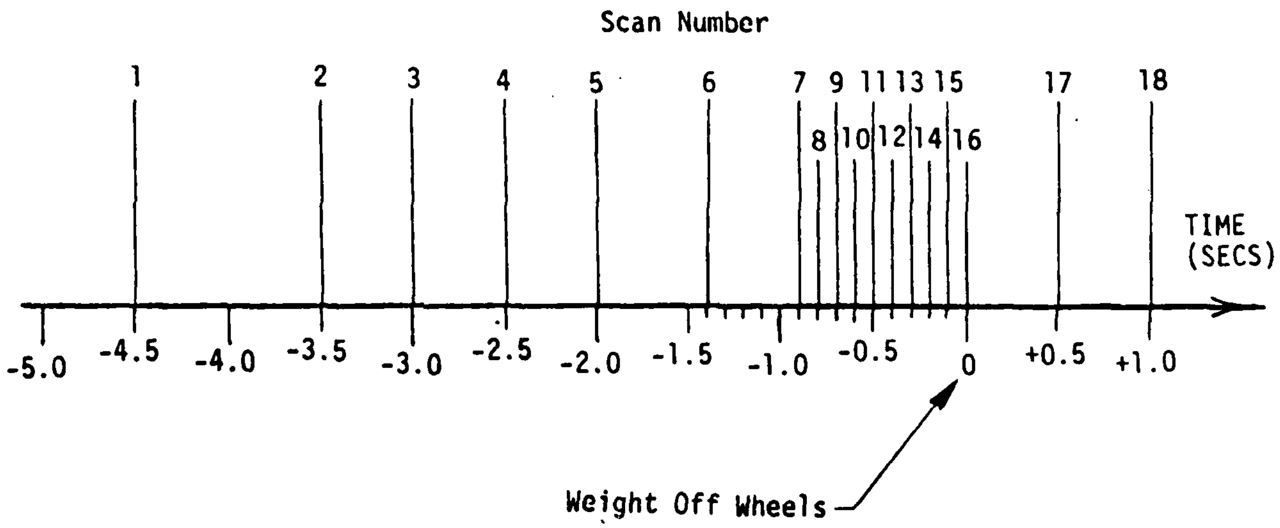


Figure 12. Automatic Takeoff Record Scan Timing

troublefree acquisition of data, suitable for gas turbine engine health trending, was achieved.

a. Description - The EDS Flight Evaluation was conducted at Langley AFB, Virginia from early April 1980 through the end of June 1981. This evaluation was conducted in three phases; the Debug phase, the Flight Evaluation phase, and the Extended Flight Evaluation phase. The applicable start and finish dates of these phases are given in Table 7. Five F-15 aircraft and eleven F100 engines, from the 1st Tactical Fighter Wing, were equipped with the EDS. The tail numbers of these aircraft and the serial numbers of these engines are given in Table 8. During the evaluation, nearly 1100 sorties, encompassing almost 1400 aircraft flight hours (AFH) and 2700 engine flight hours (EFH), were generated with the EDS aircraft/engines. In this same time, over 4100 engine operating hours (EOH) were accrued on the eleven EDS engines. Complete summaries of the EDS aircraft and engine flight statistics are given in Tables 9 and 10. A detailed account of the EDS Flight Evaluation can be found in (References 2 and 3).

b. Problems Experienced - During the course of the EDS Flight Evaluation, several problems were experienced in the acquisition of the data records used by the Advanced Trend Analysis Program. These problems involved both the rate and the engine power setting at which the data was being acquired. Late in the evaluation, several changes were made to the EDS software and an additional, quasi-stabilized trending record was added. After these changes were made, acceptable data acquisition, from both a rate and power setting standpoint, was realized.

An unacceptably low trending data acquisition rate was experienced during the Debug and Flight Evaluation phases of the EDS Flight Evaluation. This low rate was the result of the unrealistic Trend and Performance Check record engine stability requirements in use at that time. As discussed in Section II.1.d. for Software Configuration Numbers 1 and 2, the Trend record logic required stable reduced power engine operation (between 30° PLA and Intermediate) for a minimum of 3 minutes while the Performance Check record logic required stable engine operation at Intermediate power for a minimum of 2 minutes and 40 seconds. For a tactical aircraft, like the F-15, it is unlikely that the engine would be at a stable power setting for times in excess of these minimums except during cruise. However, as shown in Figure 13, the typical cruise flight conditions lie outside of either the Trend or Performance Check window limits. Trending data was acquired at a rate of 10 per 100 engine operating hours (EOH), 7 for Trend and 3 for Performance Check, during this time period. This rate represents the occasional times that the stability requirements were met during climbout and landing approach as shown in Figure 13. In Figure 14, the acquisition rate of 10 per 100 EOH is compared with the rate of 35 per 100 EOH experienced for similar trending records during the A-10/TF34 Turbine Engine Monitoring System (TEMS) Field Service Evaluation (FSE) at Myrtle Beach AFB. SCT was able to successfully trend the TF34 engine with TEMS data acquired at this 35 per 100 EOH rate. SCT's algorithm requires a relatively high data acquisition rate because of its data filtering approach (see Section IV.1).

As mentioned previously, during the Debug and Flight Evaluation phases the majority of Trend records were obtained on landing approach. Engine power settings for landing approach range from 30 to 50 degrees PLA. Figure 15

TABLE 7. EDS FLIGHT EVALUATION PHASE

PHASE	DATES FROM	TO
DEBUG	1 Apr 1980	31 Aug 1980
FLIGHT EVALUATION	1 Sept 1980	12 Dec 1980
EXTENDED FLIGHT EVALUATION	13 Dec 1980	28 June 1981

TABLE 8. EDS EQUIPPED AIRCRAFT/ENGINES

<u>AIRCRAFT TAIL NUMBERS</u> (5)

74-099
74-103
74-105
74-107
74-108

<u>ENGINE SERIAL NUMBERS</u> (11)

P680160
P680311
P680330
P680415
P680470
P680528
P680639
P680694
P680722
P680801
P680907

TABLE 9. EDS AIRCRAFT FLIGHT STATISTICS

	SORTIES/AFH			
AIRCRAFT TAIL NO.	DEBUG	FLIGHT EVALUATION	EXT. FLT. EVALUATION	TOTAL
74-099	30/34.6	68/92.2	121/150.4	219/277.2
74-103	115/136.9	39/51.7	1/1.1*	155/189.7
74-105	71/88.9	43/58.6	102/127.7	216/275.2
74-107	118/147.7	73/103.8	94/111.5	285/363.0
74-108	38/47.6	76/92.8	103/125.3	217/265.7
	372/455.7	299.399.1	421/516.0	1092/1370.8

* Sent To Warner Robbins AFB For Major Airframe Repair In December 1980.

TABLE 10. EDS ENGINE FLIGHT STATISTICS

ENGINE S/N	DEBUG	SORTIES/EFH/EOH FLIGHT EVALUATION	EXT. FLT. EVALUATION	TOTAL EDS	TOT*
680160	52/62.4/104.0	36/54.9/70.1	118/140.0/217.0	206/257.3/391.1	1664.7
680311	49/57.7/95.0	63/77.3/125.4	38/51.9/76.4	150/186.9/296.8	1575.8
680330	62/73.1/107.0	77/99.1/142.5	93/112.8/169.7	232/285.0/419.2	1369.6
680415	23/29.9/57.4	74/95.0/142.2	104/127.7/200.8	201/252.6/400.4	974.3
680470	122/152.2/254.4	40/51.9/85.4	97/120.1/176.4	259/324.2/516.2	863.6
680528	61/73.4/115.6	38/47.2/78.3	96/118.7/177.6	195/239.3/371.5	1154.4
680639	70/87.9/152.8	45/59.9/84.6	42/50.9/78.6	157/198.7/316.0	769.7
680694	115/136.9/211.4	39/50.9/82.3	39/47.5/75.0	193/235.3/368.7	1271.3
680722	58/72.5/112.2	63/84.5/126.0	0/0.0/3.0	121/157.0/241.2	906.0
680801	117/146.4/224.6	13/18.4/29.6	94/114.7/172.0	224/279.5/426.2	1252.4
680907	13/15.1/37.4	66/94.2/138.4	122/149.9/212.2	201/259.2/388.5	1065.8
	742/907.5/1471.8	554/733.3/1105.3	843/1034.2/1558.7	2139/2675.0/4135.8	

*Total Operating Time (Hours) As Of 28 June 1981

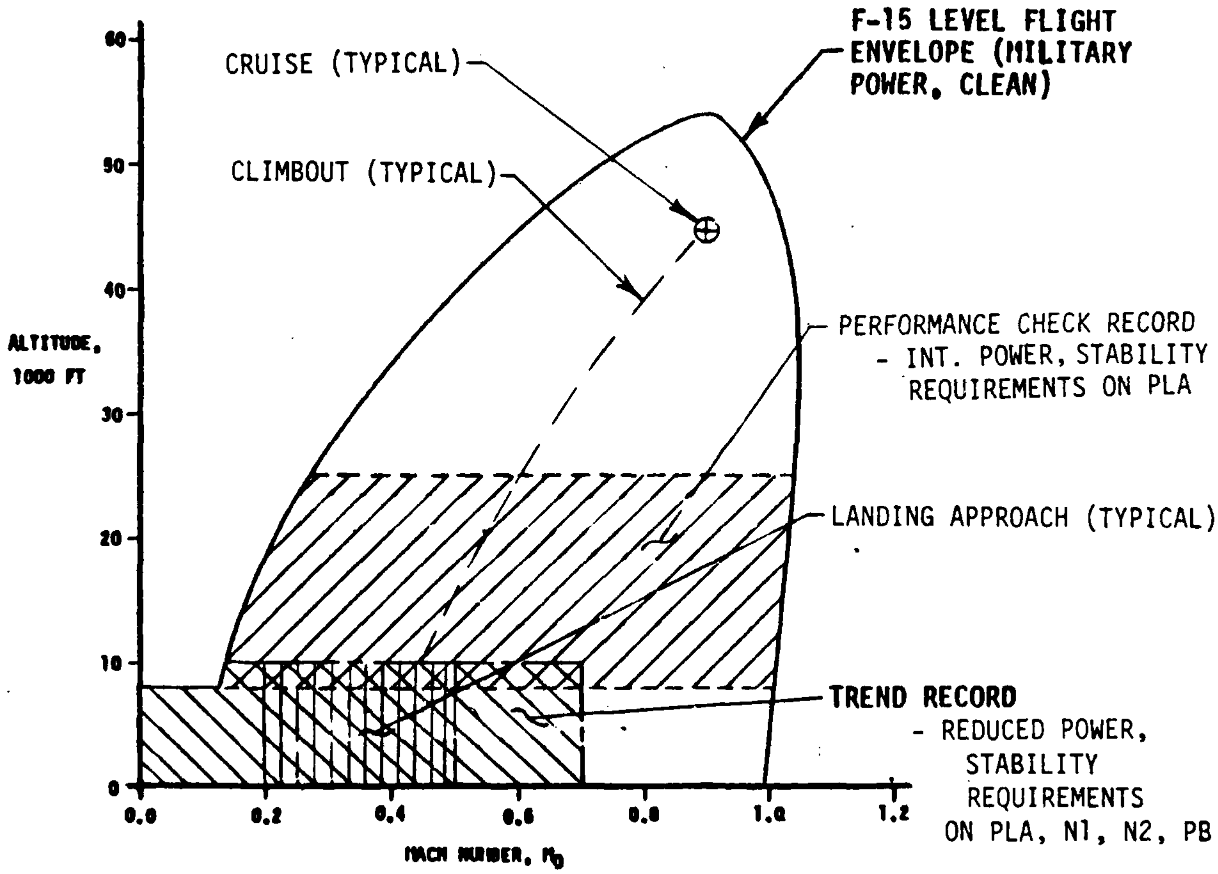


Figure 13. Stabilized Inflight Data Records

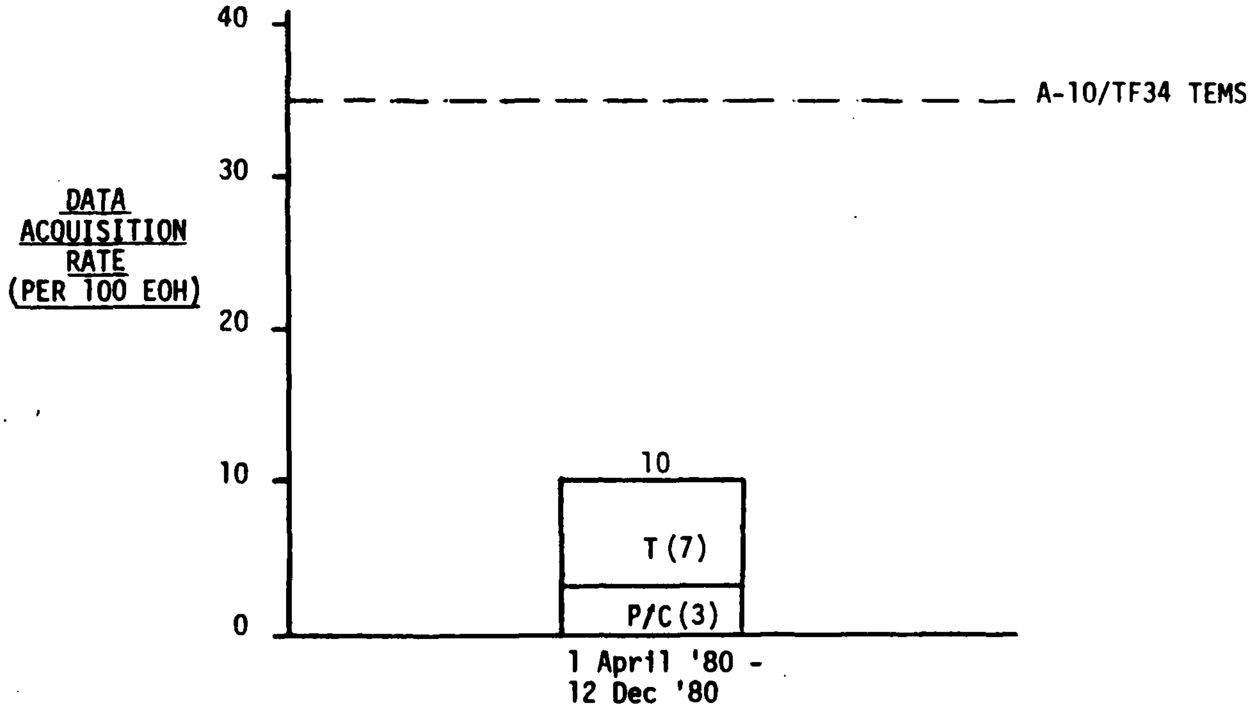


Figure 14. EDS Trending Data Acquisition Rate Software Config. No. 1

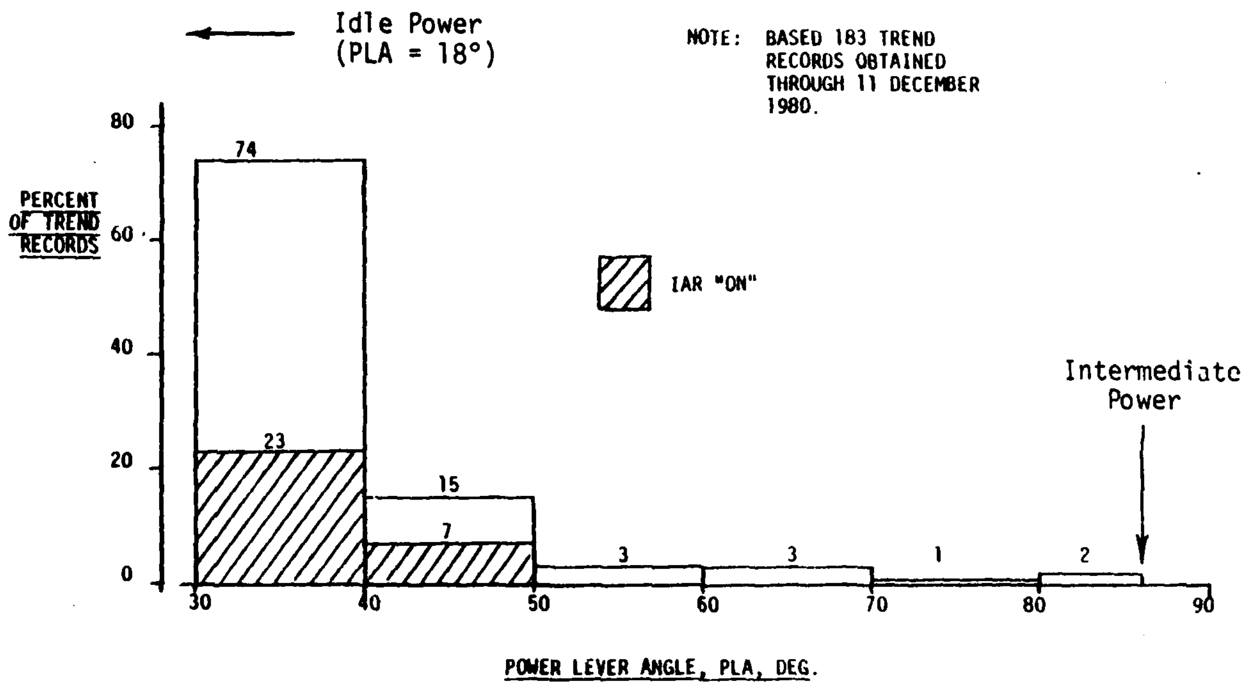


Figure 15. Trend Record Power Level Distribution
Software Config. No. 1

shows that almost 90% of all the Trend records obtained during this time period were at an engine power setting below 50° PLA. The usefulness of this data for engine health trending is uncertain. The operating point of the F100 engine is much less repeatable at these reduced power settings, where it is hydromechanically determined by the UFC, than it is at Intermediate power, where it is electro-mechanically "fine tuned" by the EEC. This increased operating point uncertainty at reduced power may be of sufficient magnitude to effectively mask any real performance trends that may be present. Further complicating this situation is the fact that some of the reduced power Trend data was recorded with the F100 Idle Area Reset (IAR) function activated. The IAR function is activated when the EEC is on (normal), when PLA is less than 51 degrees, and when the aircraft landing gear are down. The IAR function reduces engine thrust during final landing approach and pre/post-flight taxi by increasing the engine exhaust nozzle area (AJ) over the basic UFC scheduled area as shown in Figure 16. The percentage of Trend records for which the IAR function was activated is indicated by the shaded areas shown in Figure 15. This nozzle uncertainty further increased the low power engine operating point uncertainty.

A power level problem with the Performance Check records was also experienced during the Debug and Flight Evaluation phases. Because of an error made in programming the Performance Check software, some of these records were obtained with the engine in augmentation. The increased nozzle area uncertainty associated with augmented engine operation results in this data being of doubtful worth for engine health trending for the same reasons mentioned previously in the discussion of the low power Trend record problem. Approximately 30% of the Performance Check records obtained during these two Flight Evaluation phases were affected by this software problem before it was corrected in mid-November of 1980.

During the first three and a half months of the Extended Flight Evaluation, the low trending data acquisition rate problem was made worse. During this time period, the trending data acquisition rate dropped to 2 per 100 EOH, 1 for Trend and 1 for Performance Check records, as shown in Figure 17. There were two reasons for this decreased rate:

1) During the Extended Flight Evaluation, the EDS was "turned over" to the USAF maintenance personnel. These personnel tended to transfer the EDS data stored in the on-board DPU only once a day, after each aircraft had flown its scheduled number of sorties, rather than after each sortie as the MCAIR EDS support team had previously done. This increased the number of aircraft flight hours and, of course, engine operating hours per DPU data transfer. Since at most one Trend and one Performance Check record can be obtained per DPU data transfer, this greatly reduced the potential, and actual, trending data acquisition rate per engine operating hour.

2) Pratt and Whitney, who had control of the EDS software, increased the minimum Trend record PLA limit from 30° to 45°. This change was incorporated as Software Configuration Number 2 as discussed in Section II.1.d. This change was made in an attempt to remedy the low power Trend record problem discussed earlier. It was thought that perhaps some higher power Trend records, obtained

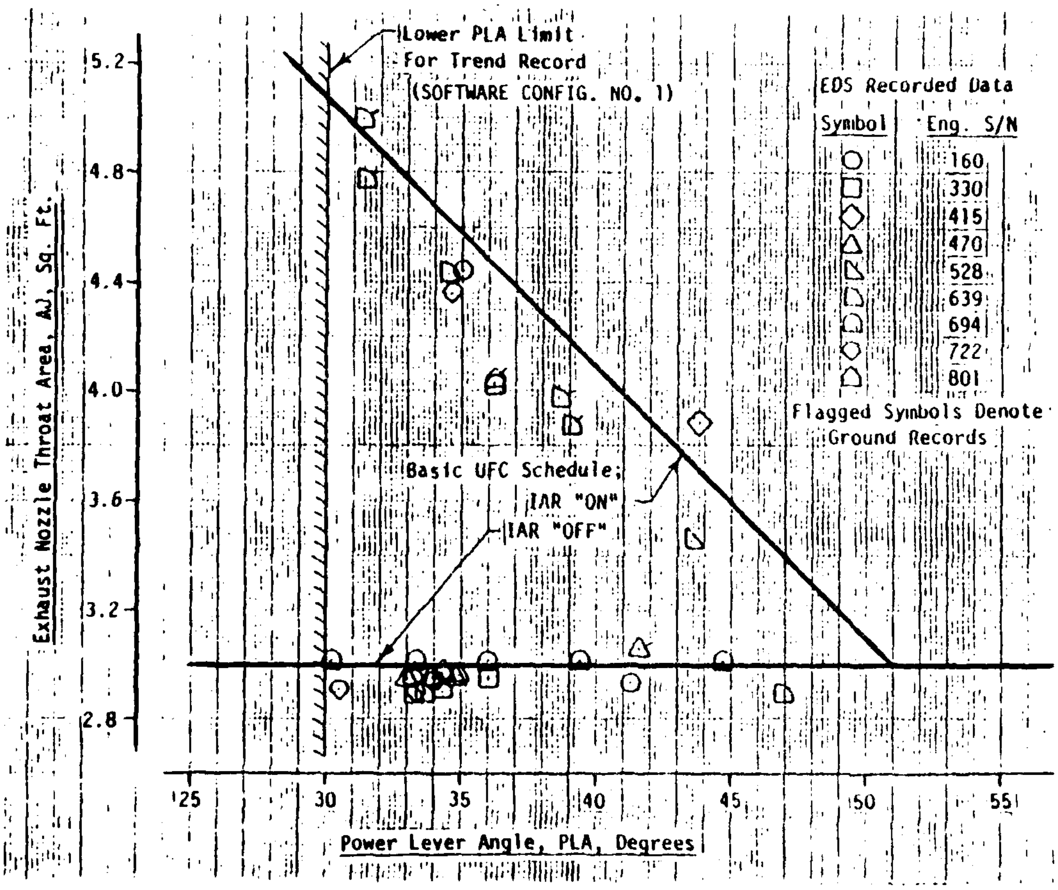


Figure 16. Trend Record Nozzle Position

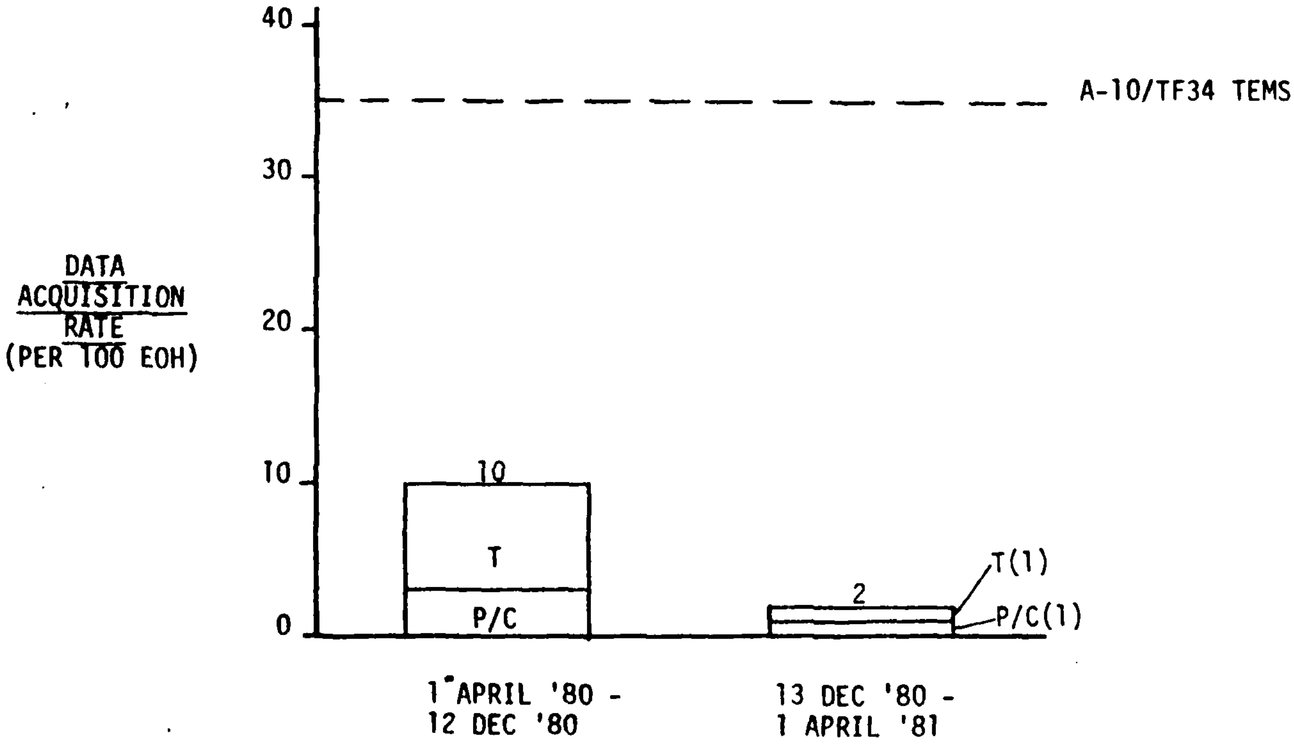


Figure 17. EDS Trending Data Acquisition Rate Comparison
Software Config. No. 1

earlier in a sortie, were being overwritten, and therefore lost, by the lower power records obtained late in each sortie during landing approach. Obviously, this was not the case as the low Trend record acquisition rate, 1 per 100 EOH, indicates.

A joint AFWAL/SCT/MCAIR Technical Coordination Meeting (TCM) was held in mid-February 1981 to formulate a plan to solve the trending data acquisition problems that had been experienced. Two recommendations were made to ASD/YZ100, the EDS Program sponsoring organization. These recommendations called for relaxed Trend and Performance Check stability requirements, to increase the data acquisition rate, and an increased Trend record minimum PLA limit, to eliminate the low power Trend record problem. These recommendations were approved by ASD/YZ100 and were incorporated as Software Configuration Number 3 (see Section II.1.d). Pratt and Whitney Aircraft also approved these recommended changes with the provision that a stabilization timer be added to both the Trend and Performance Check software and that the record overwrite logic be revised to store only the Trend and the Performance Check record with the longest stabilization time. These timers and the revised overwrite logic were incorporated as Software Configuration Number 4 (see Section II.1.d).

The EDS software changes incorporated in Software Configuration Numbers 3 and 4 were successful in solving the trending data acquisition problems. Figure 18 compares the trending data acquisition rate, 41 per 100 EOH, experienced after early April of 1981 with the rates experienced earlier in the Flight Evaluation. Note that this acquisition rate is higher than the reference rate of 35 established by the A-10/TF34 TEMS.

The software changes incorporated in Software Configuration Numbers 3 and 4 were also successful in eliminating the low power Trend record problem. This success is illustrated in Figure 19. Over 50% of the Trend records obtained after the incorporation of Software Configuration Number 3 were at, or within 10° PLA of, Intermediate power and 97% were within 20° PLA. The Trend and Performance Check stabilization time distributions, for Software Configuration Number 4, are shown in Figures 20 and 21. The average stabilization requirements had not been relaxed, only 2 Trend records and 14 Performance Check records would have been obtained in the nearly three month time period that Configuration Number 4 was in use.

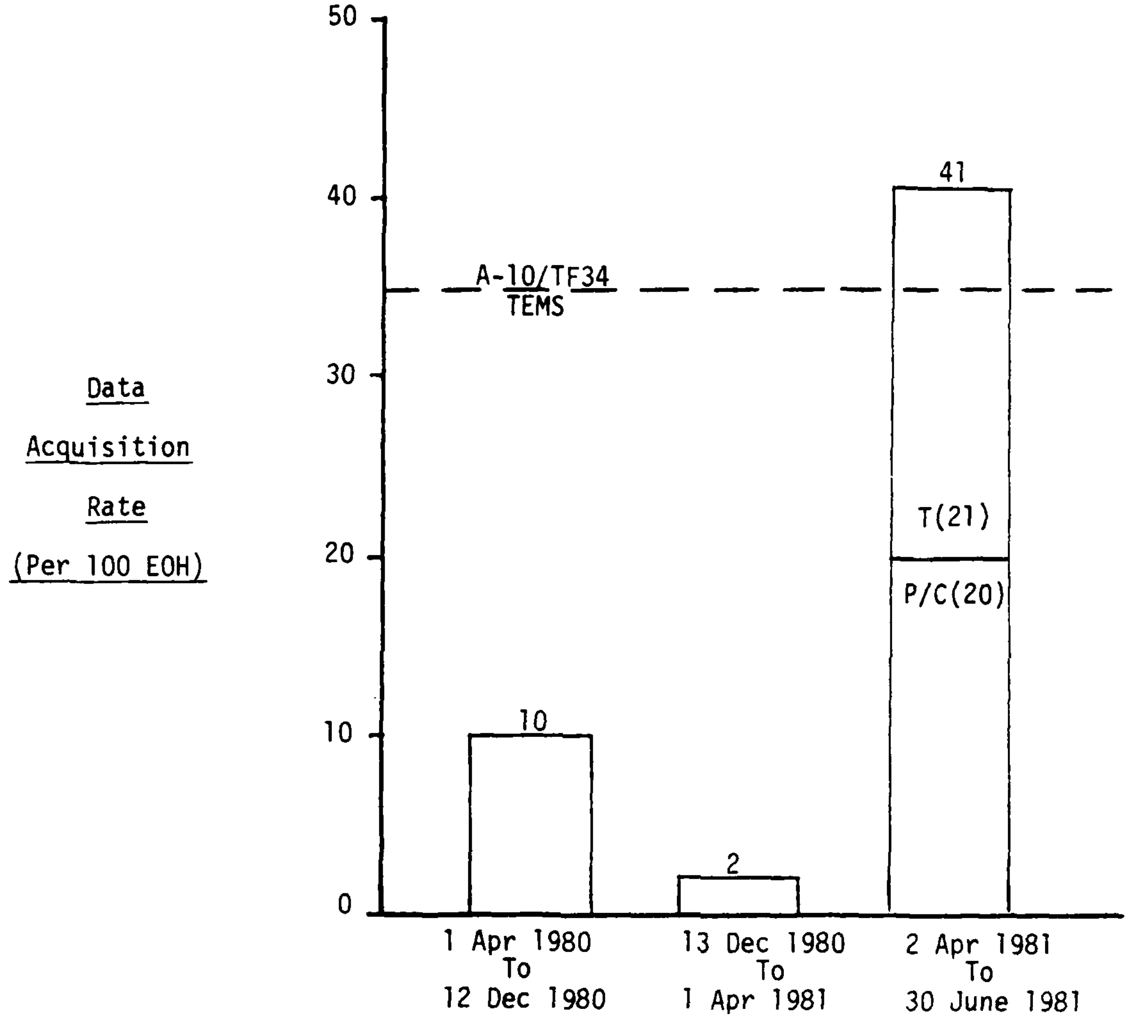


Figure 18. EDS Trending Data Acquisition Rate Comparison
Software Config. Nos. 3 and 4

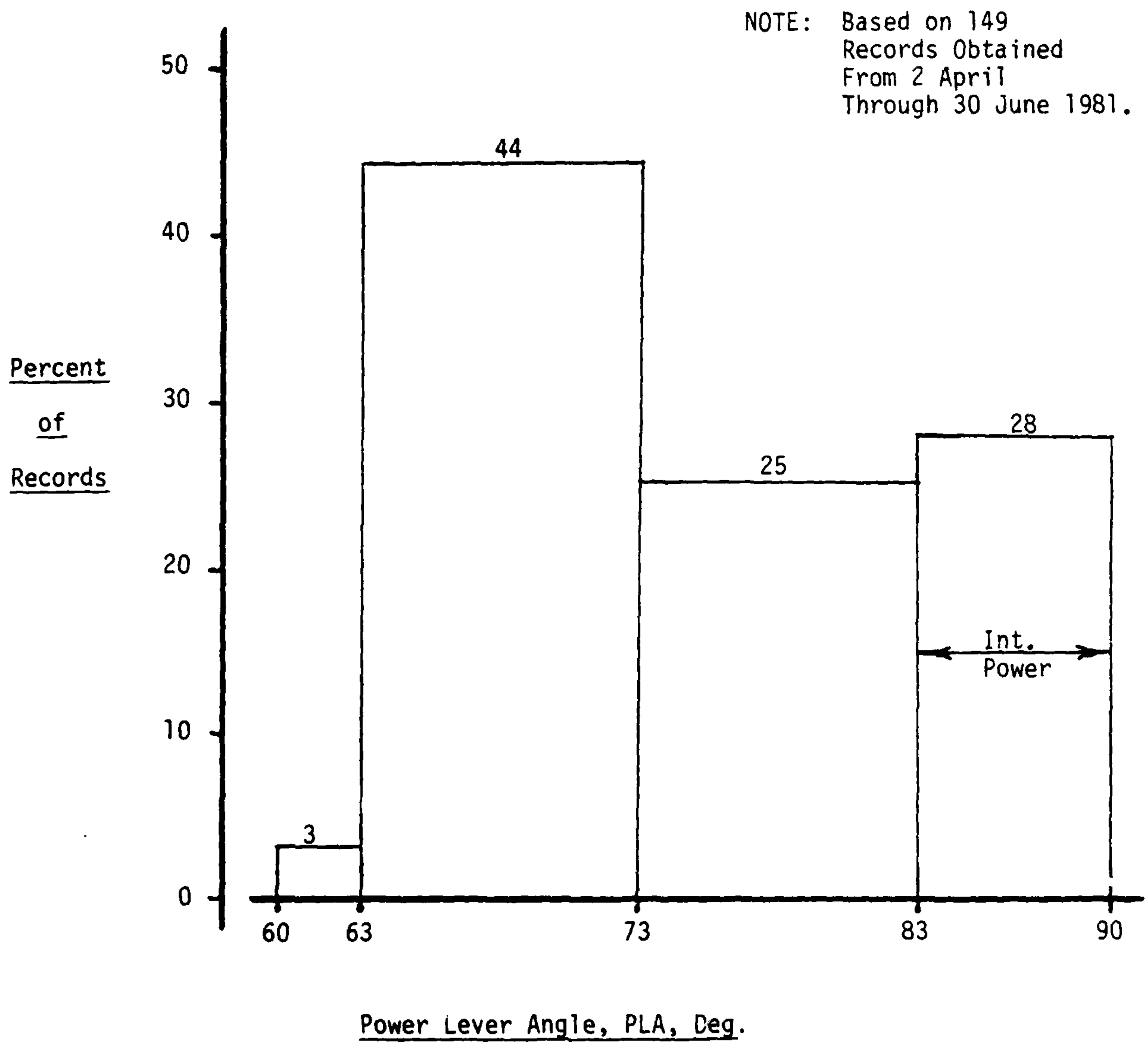


Figure 19. Trend Record Level Distribution Software Config. Nos. 3 and 4

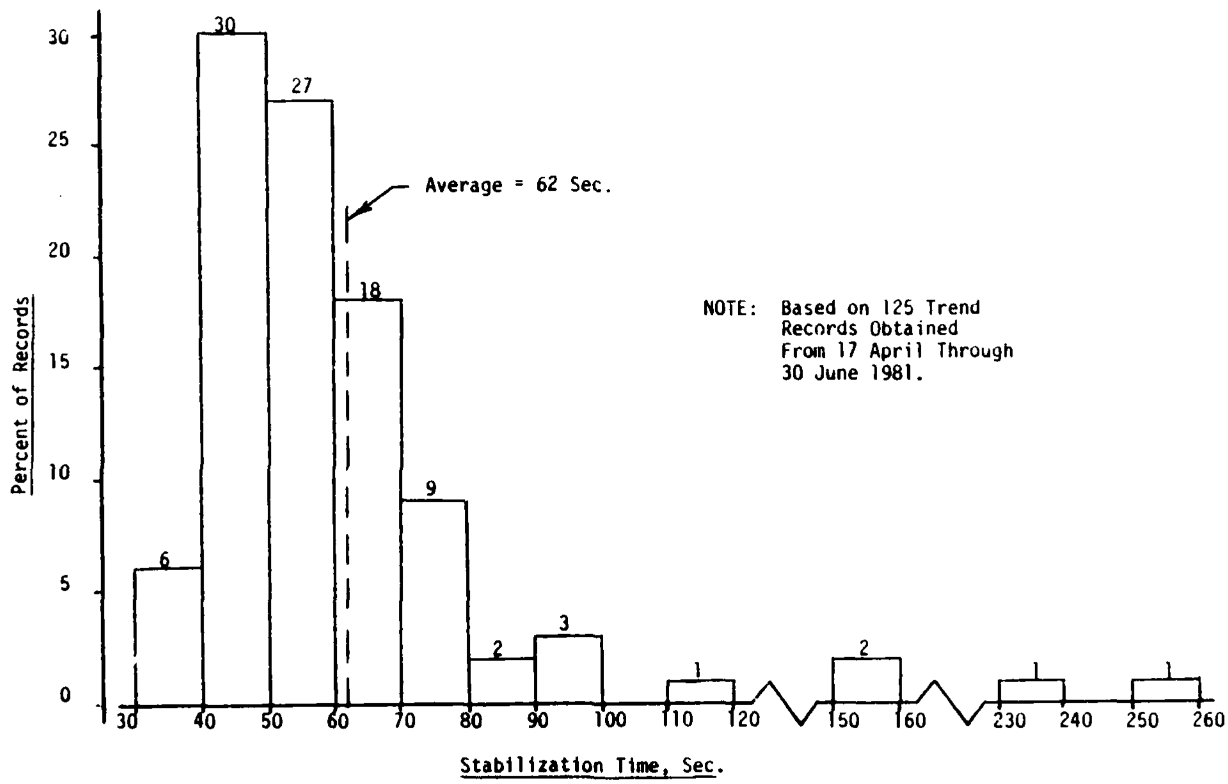


Figure 20. Trend Record Stabilization Time Distribution Software Config. No. 4

SOFTWARE CONFIG. NO. 4

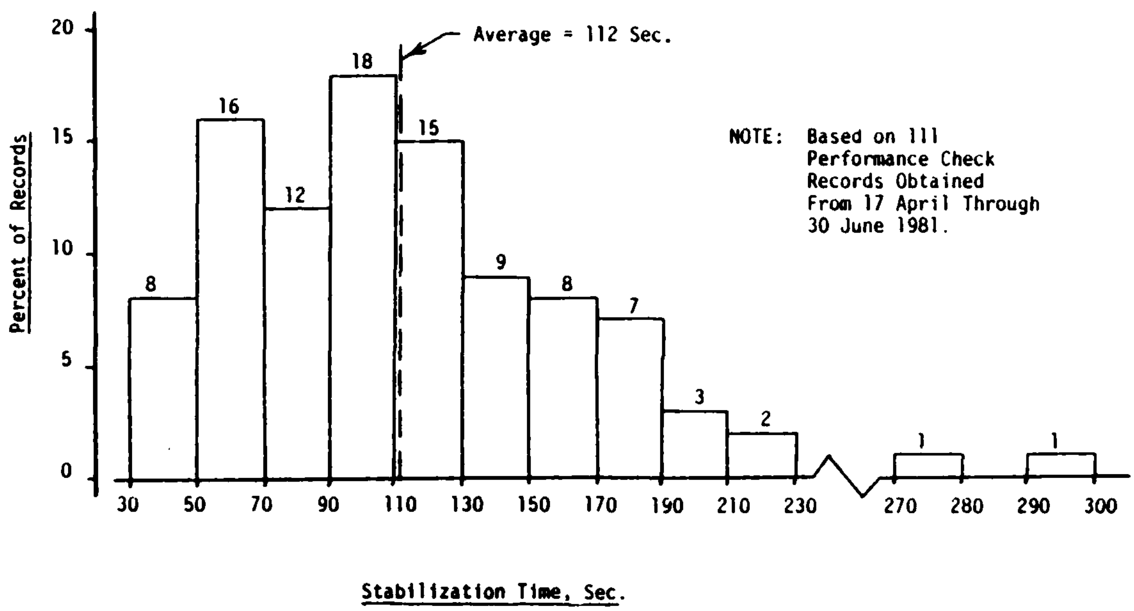


Figure 21. Performance Check Record Stabilization Time Distribution

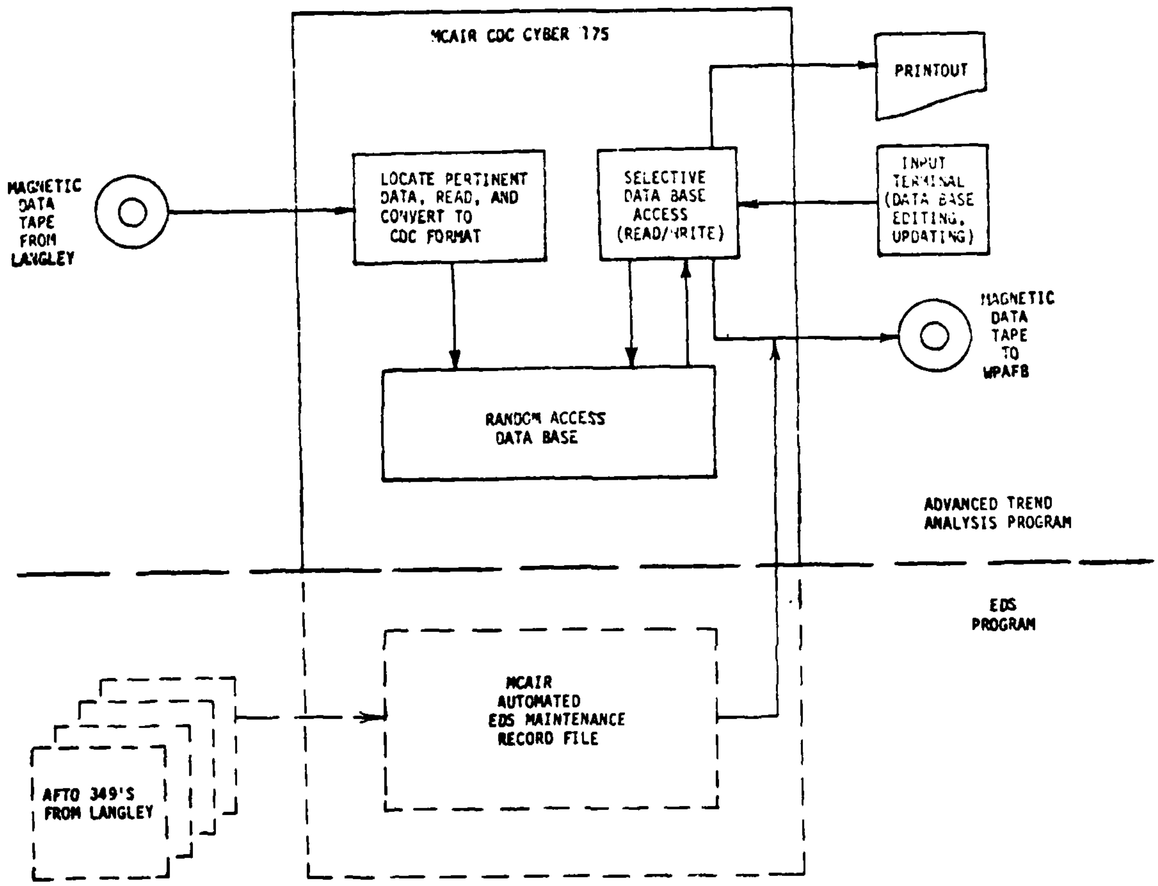
SECTION III

DATA TRANSMITTAL

An important element of the Advanced Trend Analysis Program was the Langley/St. Louis/WPAFB data link. This link was used to transmit EDS Flight Evaluation data from Langley AFB through MCAIR in St. Louis to the Computer Center at WPAFB. To enable the USAF (AFWAL/POTC) and SCT to interface with this data link, details of the link had to be specified. These details are documented in this section and include discussions of the data flow and the formats used to transmit the data. In addition, a summary of the data transmittals is presented.

1. DATA FLOW - A data link was established between Langley, St. Louis, and WPAFB. Data flow along this link is illustrated in Figure 22. The magnetic data tape from Langley, discussed in Section II.1.a, was periodically transferred to St. Louis via private/commercial air routes. Once in St. Louis, this tape was input to the MCAIR Cyber 175 Computer for processing and editing. The MCAIR Automated EDS Maintenance Record File, discussed in Section II.2, was established on the Cyber 175 Computer as part of the EDS Program. Another data tape, consisting of EDS recorded data and maintenance record data was transferred to the Computer Center at WPAFB. This tape transfer took place monthly until the final 3 months of the Extended Flight Evaluation at which time bi-weekly transmittals were initiated. The WPAFB CDC Cyber Computer read, interpreted, and processed the data tape incoming from St. Louis. Software, written by SCT, entered the data into a large and specially structured data base. Once in this data base, the data was accessible to SCT's executive modules for fault detection/isolation, gas path analysis, and trending.

a. EDS Recorded Data - The MCAIR CDC Cyber 175 Computer read, interpreted, and processed the data tape incoming from Langley. Since this tape was generated by the Harris Computer at Langley, which uses a basic 24 bit word structure, it had to be interpreted on a bit-by-bit basis and translated into the basic 60 bit word structure used by the CDC. Data on the tape, pertinent to the Advanced Trend Analysis Program, was located, read, and then converted to the CDC word structure for additional processing. This pertinent data consisted not only of the parameters discussed in Section II.1.b, for the Trend, Performance Check, Average, and later, Takeoff records, but also included the data required to determine which, if any, of the remaining detectable events, discussed in Section II.1.a, occurred since the previous data transfer. Event detection flags were set and the translated data was written to a random access data base. This data base allowed selective access of the data for quality verification and editing. Quality verification was accomplished by inspection of the data for unreasonable values and also by comparison with hardcopies of the data generated at Langley. Once the data had been verified and edited, if required, it was copied to the magnetic tape, along with the maintenance record data discussed in the next section, for transferral to WPAFB. The format of this tape and the actual data transmittals are discussed in Sections III.2 and III.3.



NOTE: In Early 1981 (After Transmittal No. 6), AFTO 349 Maintenance Record Data Was Manually Input To An SCT Computer Via Their Automated Maintenance Entry Program

Figure 22. Langley/St. Louis/WPAFB Data Flow

b. Maintenance Records - Originally, the EDS Flight Evaluation maintenance records, discussed in Section II.2, were to be processed and analyzed in St. Louis by MCAIR Maintainability/Reliability personnel. Hardcopy maintenance record files for all the aircraft and engines involved in the EDS Flight Evaluation were to have been established and the MCAIR Automated EDS Maintenance Record File was to have been set up on the MCAIR Cyber 175 Computer. All of this effort was to have been done to support the calculation of Life Cycle Cost (LCC) savings attributable to the EDS. Unfortunately, the contractual requirement for this EDS LCC analysis was deleted during the Debug phase of the Flight Evaluation. While most of the hardcopy maintenance records continued to be sent to St. Louis from Langley, no effort was expended by the St. Louis based EDS personnel to keep the Automated EDS Maintenance Record File up to date. This file consists of AFTO 349 data condensed into an 80 character per record format to facilitate computer storage and automated record retrieval/processing. The labor intensive task of manually inputting these AFTO 349 records to this file became the responsibility of the Advanced Trend Analysis Program. Until early 1981, this file was updated on roughly a monthly basis and copied to the data tape referred to in Section III.1.a, containing the EDS recorded data, for transmittal to WPAFB. The format of this tape, for both the EDS recorded data file and the maintenance record file, will be discussed in Section III.2. Beginning with EDS Data Transmittal Number 7, these maintenance records were no longer transmitted to WPAFB on the same data tape as the EDS recorded data. Instead, these records were directly input to an SCT computer in Palo Alto, CA. This was accomplished through the use of a computer program, developed by SCT, which interactively prompted the user to manually input the records in the same format as the MCAIR Automated EDS Maintenance Record File. This program greatly facilitated the manual input of these records and was used for the remainder of the program. The content and transmittal dates of the 16 Advanced Trend Analysis Program EDS data transmittals will be discussed in Section III.3.

2. DATA FORMAT - The format of the data tape transferred from St. Louis to WPAFB varied over the course of the Advanced Trend Analysis Program. Early in the program, this tape consisted of two data files; an EDS Recorded Data File and a Maintenance Record File. Early in 1981, beginning with EDS Data Transmittal Number 7, the Maintenance Record File was deleted from the tape leaving only the EDS Recorded Data File. Then, beginning with Transmittal Number 10, when Trend and Performance Check Software Configurations 3 and 4 were implemented (see Section II.1.d), the format of this EDS Recorded Data File was revised and a number of additional files, the Automatic Takeoff Record Data Files, were added. However, the general characteristics of this data tape (density, data blocking, number of tracks, file separations, etc.) remained constant throughout the program. These characteristics are summarized in Table 11. The formats of the EDS Recorded Data File, the Automatic Takeoff Record Data Files, and the Maintenance Record File are discussed in detail in the following sections.

a. EDS Recorded Data - The EDS Recorded Data File and the Automatic Takeoff Record Data Files were made up of multiple data entries; one for every DDU data record. As discussed in Section II.1.a, data stored in the DDU could consist of in-flight and/or ground run records. If the DDU

TABLE 11. DATA TAPE CHARACTERISTICS

Unlabeled
Blocked (512 Words/Block)
9 Track
Phase Encoded (PE)
1600 BPI
Binary Data

- Records Separated By Standard CDC End-Of-Record (EOR) Marks
- Files Separated By Standard End-Of-File (EOF) Mark
- End Of Tape Denoted By Double EOF Mark

was used to transfer data from the DPU or DCU directly to the AGP, then the data consisted of only in-flight records. However, if the DDU was used for diagnostic trouble-shooting prior to transferring data to the AGP, the data could have consisted of both in-flight and ground-run records. The EDS Flight Evaluation Plan (Reference 1) called for a DDU data record to be generated after every sortie, diagnostic ground-run, or sortie/ground-run combination. However, during the course of the Flight Evaluation, this was not always achieved. Remote base deployment, rapid aircraft turn-around during a sortie generation surge, etc., sometimes resulted in DDU data records that encompassed more than one sortie, diagnostic ground-run, or sortie/ground-run combination. Both the EDS Recorded Data File and the Automated Takeoff Record Data File(s) store the recorded data by engine serial number.

EDS Recorded Data File - Data entries for the EDS Recorded Data File consisted of several combinations of four basic data blocks; the global, the Trend record, the Performance Check record, and the Average record data blocks. Every data entry consisted of at least a global data block made up of an identifier record and a global data record. For installed operation, either in-flight or on the ground, a data entry may have also consisted of a Trend record and/or a Performance Check record data block if either, or both, of these records had been stored since the previous data transfer. For uninstalled operation, the global data block could have been joined by anywhere from zero to four Average record data blocks to make up a data entry. Trend record, Performance record, and Average record data blocks each consist of an identifier record and a stored data record. The basic structure for an EDS Recorded Data File data entry is shown in Table 12.

The structure of the EDS Recorded Data File identifier records is identical for all four types of data blocks and consists of 9 words. A description of these words for EDS Transmittal Numbers 1 through 9 is given in Table 13. Beginning with Transmittal Number 10, a Trend and Performance Check Record Software Configuration Flag was added to Word 9 of the identifier record. This made word 9 a 2-digit integer with the least significant digit being the Data Block Identifier Flag, and the most significant digit being the Software Configuration Flag as defined in Table 14.

An EDS Recorded Data File global data record consists of 30 words. A description of these 30 words is given in Table 15. This description is applicable for all EDS data transmittals.

A stored data record consists of 45 words. This record is applicable for Trend, Performance Check, and Average record data. A description of these 45 words is given in Table 16. Note that for Software Configuration Number 4 only, Word 1 becomes STABTM, the time that the engine was within the specified stability window before the record was taken.

Automatic Takeoff Record Data Files - The structure of the Automatic Takeoff Record Data Files, first added on Transmittal Number 10, is very similar to that of the EDS Recorded Data File. However, since the Takeoff record consisted of an 18 data scan time history rather than a single scan time average, like the Trend, Performance Check and Average records, some

TABLE 12. BASIC DATA ENTRY STRUCTURE
EDS Recorded Data File

INSTALLED DATA

GLOBAL DATA BLOCK

Identifier Record (9 Words)
Global Data Record (30 Words)

TREND RECORD DATA BLOCK*

Identifier Record (9 Words)
Stored Data Record (45 Words)

PERFORMANCE CHECK RECORD DATA BLOCK*

Identifier Record (9 Words)
Stored Data Record (45 Words)

UNINSTALLED DATA

GLOBAL DATA BLOCK

Identifier Record (9 Words)
Global Data Record (30 Words)

AVERAGE RECORD DATA BLOCK **

Identifier Record (9 Words)
Stored Data Record (45 Words)

* Zero Or One Of These Blocks May Be Present.
** Zero To Four Of These Blocks May Be Present.

TABLE 13. EDS RECORDED DATA FILE IDENTIFIER RECORD STRUCTURE
Data Transmittals 1 Through 9

WORD	SYMBOL	DESCRIPTION
1	ENGSN	Engine Serial Number
2	RECDT	Julian Date of Data Record
3	RECYR	Last Two Digits of Year of Data Record
4	ACFTN	Aircraft Tail Number
5	FLTNO	Aircraft Sortie Number
6	DDUDT	Julian Date of Data Collection
7	DDUYR	Last Two Digits of Year of Data Collection
8	DDUTM	Time of Data Collection Military Hours And Minutes
9	BLKID	Data Block ID = 1 For Global Data Block = 2 For Trend Record Or Average Record Data Block = 3 For Performance Check Record Data Block

NOTES:

(1) Words 4 and 5 Will Be Zero For Uninstalled Data.
(2) All Words Are Integers.

TABLE 14. REVISED EDS RECORDED DATA FILE IDENTIFIER RECORD DESCRIPTION
Transmittal Number 10 Through 16

- Word 9 Is A 2-Digit Integer

D_M D_L

D_L = Least Significant Digit
= Data Block ID Flag*

D_M = Most Significant Digit
= Software Configuration Flag
= 0 For Configuration No. 1**
= 1 For Configuration No. 2**
= 2 For Configuration No. 3**
= 3 For Configuration No. 4**

* See Table 13 For Definition Of ID Flag.
** See Section II.1.d For Description Of Software Configurations.

TABLE 15. GLOBAL DATA RECORD DESCRIPTION

WORD	SYMBOL	DESCRIPTION	UNITS
1	FLG1	Hot Start Event Detection Flag	N/D
2	FLG2	N2 Overspeed Event Detection Flag	N/D
3	FLG3	FTIT Overtemp Event Detection Flag	N/D
4	FLG4	FTIT Spread Event Detection Flag	N/D
5	FLG5	RCVV Out-of-Limits Event Detection Flag	N/D
6	FLG6	Main Oil Pressure Out-of-Limits (Priority 2) Event Detection Flag	N/D
7	FLG7	Main Oil Pressure Out-of-Limits (Priority 1) Event Detection Flag	N/D
8	FLG8	No. 4 Bearing Oil Scavenge Pressure Out-of-Limits Event Detection Flag	N/D
9	FLG9	Engine Stall Event Detection Flag	N/D
10	FLG10	EEC Fault Event Detection Flag	N/D
11	FLG11	Inlet Vibration Event Detection Flag	N/D
12	FLG12	Difuser Vibration Event Detection Flag	N/D
13	FLG13	Gearbox Vibration Event Detection Flag	N/D
14	FLG14	Trend Record Storage Flag	N/D
15	FLG15	Performance Check Storage Flag	N/D
16	FLG16	Pilot Option Record Storage Flag	N/D
17	FLG17	Main Fuel Pump Deterioration Event Detection Flag	N/D
18	FLG18	Augmentor Blowout/Mislight Event Detection Flag	N/D
19	FANSN	Inlet/Fan Module Serial Number	N/D
20	CORSN	Core Module Serial Number	N/D
21	HITSN	High Turbine Serial Number	N/D
22	LOTSN	Fan Drive Turbine Serial Number	N/D

TABLE 15 (Concluded). GLOBAL DATA RECORD DESCRIPTION

WORD	SYMBOL	DESCRIPTION	UNITS
23	AUGSN	Augmentor Module Serial Number	N/D
24	ENGOT	Total Engine Operating Time	Hours
25	ENGFT	Total Engine Flight Time	Hours
26	HS1TM	Hot Section 1 Time	Hours
27	HS2TM	Hot Section 2 Time	Hours
28	HS3TM	Hot Section 3 Time	Hours
29	LC1CT	Type I LCF Count	N/D
30	LC3CT	Type III LCF Count	N/D

NOTES: 1) Code For All Event Detection/Record Storage Flags
= 0 For Event Not Detected/Record Not Stored
= 1 For Event Detected/Record Stored

2) Words 1 Through 18 Are Integers.
Words 19 Through 23 Are Alphanumeric.
Words 24 Through 30 Are Single Precision Floating Point Real Numbers.

TABLE 16. STORED DATA RECORD DESCRIPTION
EDS Recorded Data File

WORD(S)	SYMBOL	DESCRIPTION	UNITS
1	SYSTM	Time of Data Record (Gets Reset To 0.0 After Each Data Collection)	Seconds
1*	STABTM	Engine Stable Time	Seconds
2	H	Altitude	Feet
3	MO	Mach Number	N/D
4	TT2	Engine Inlet Temperature	°C
5	PT2	Engine Inlet Pressure	PSIA
6	N1	Low Spool Rotor Speed	RPM
7	N2	High Spool Rotor Speed	RPM
8	TT2.5	Fan Exit Duct Temperature	°C
9	PT2.5	Fan Exit Duct Pressure	PSIA
10	TS3	Compressor Exit Skin Temperature	°C
11	WFT	Total Fuel Flow	PPH
12	PB	Engine Burner Pressure	PSIA
13	FTITAVG	Average Fan Turbine Inlet Temperature	°C
14-20	FTIT1 - FTIT7	Individual Fan Turbine Inlet Temperature	°C
21	PT6	Augmentor Inlet Pressure	PSIA
22	AJ	Exhaust Nozzle Throat Area	Sq. Ft.
23	RCVV	Rear Compressor Variable Vane Angle	DEG
24	PLA	Power Lever Angle	DEG
25	VIBI	Inlet Case Vibration, Overall	Mils
26	VIBI1	Inlet Case Vibration, N1 Narrowband	Mils
27	VIBI2	Inlet Case Vibration, N2 Narrowband	Mils
28	VIBD	Diffuser Case Vibration, Overall	Mils

TABLE 15 (Concluded). STORED DATA RECORD DESCRIPTION
EDS Recorded Data File

WORD(S)	SYMBOL	DESCRIPTION	UNITS
29	VIBD1	Diffuser Case Vibration, N1 Narrowband	Mils
30	VIBD2	Diffuser Case Vibration, N2 Narrowband	Mils
31	VIBG	Gearbox Vibration, Overall	Mils
32	VIBGP	Gearbox Vibration, PTO Narrowband	Mils
33	LVI	EEC Level I Fault (1.0 = ON)	N/D
34	LVII	EEC Level II Fault (1.0 = ON)	N/D
35	LVIII	EEC Level III Fault (1.0 = ON)	N/D
36	MFPDT	Main Fuel Pump Deterioration Signal (1.0 = ON)	N/D
37	MOT	Main Oil Temperature	°C
38	MOP	Main Oil Pressure	PSID
39	MPB	Main Breather Pressure	PSIA
40	PSCV4	No. 4 Bearing Scavenge Pressure	PSIA
41	TFO	Fuel Inlet Temperature	°C
42	PFO	Fuel Inlet Pressure	PSIA
43	PF1	Fuel Pump Boost Pressure	PSIA
44	PF2	Fuel Pump Discharge Pressure	PSIA
45	PF1A	Augmentor Fuel Pump Discharge Pressure	PSIA

NOTE: All Words Are Single Precision Floating Point Real Numbers

* For Trend/Performance Check Record Software Configuration Number 4 Only.

differences do exist. A typical Automatic Takeoff Record Data File entry is shown in Table 17. Each data entry consists of a global data block and 18 Takeoff record data blocks, one for each data scan. Each global data block consists of an identifier record and a global data record. Each Takeoff record data block consists of an identifier record and a stored data record. The exact timing of the 18 data scans which make up an Automatic Takeoff record is discussed in Section II.1.d.

The Automatic Takeoff Record Data File identifier records are the same for both global and Takeoff record data blocks. Each identifier record consists of 7 words as shown in Table 18. Note the similarity between this Automatic Takeoff Record Data File identifier record and the EDS Recorded Data File identifier record, Table 13.

The Automatic Takeoff Record Data File global record is identical in every way to the EDS Recorded Data File global record, Table 15.

The Automatic Takeoff Record Data File stored data record consists of 45 words. This record is identical to the EDS Recorded Data File stored data record, Table 16 (Software Configuration Numbers 1 through 3), except for word 36 which is an Anti-Ice Discrete Flag as shown in Table 19.

Usually, more than one Automatic Takeoff Record Data File was written on the magnetic tape transferred to WPAFB. This was done to limit each file to a practical size. Because each Automatic Takeoff Record Data File data entry consisted of a global block and 18 takeoff word data blocks, the size of each entry was quite large. Coordination with SCT, established a practical limit of 15 data entries per file.

b. Maintenance Records - The MCAIR Automated EDS Maintenance Record File consisted of seven record types. These types cover all of the possible maintenance scenarios for which an AFTO Form 349 is normally used. The seven record types are:

1) On-Equipment (Aircraft or Engine)
2) Off-Equipment
3) Removal of Serialized Component
4) Installation of Serialized Component
5) Removal/Installation of Aircraft Engine
6) Discrepancy/Corrective Action
7) Part Replaced During Repair

A description of each record is given in Table 20. USAF Technical Order 1F-15A-06 should be consulted to decipher the various codes used in this file. As discussed previously, transferral of this file to WPAFB ceased after EDS Data Transmittal Number 6. For the remainder of the program, AFTO Form 349 data was input directly to an SCT computer using the SCT Automated Maintenance Record Input Computer program. The format of this directly input data was identical to the format of the MCAIR Automated EDS Maintenance Record File given in Table 20.

TABLE 17. AUTOMATIC TAKEOFF RECORD DATA ENTRY STRUCTURE

GLOBAL DATA BLOCK

Identifier Record (7 Words)
Global Data Record (30 Words)

TAKEOFF RECORD DATA BLOCK (SCAN 1)

Identifier Record (7 Words)
Stored Data Record (45 Words)

o
o
o
o
o
o
o
o
o
o
o
o
o
o

TAKEOFF RECORD DATA BLOCK (SCAN 18)

Identifier Record (7 Words)
Stored Data Record (45 Words)

TABLE 18. TAKEOFF RECORD FILE IDENTIFIER RECORD DESCRIPTION

WORD	SYMBOL	DESCRIPTION
1	ENGSN	Engine Serial Number
2	RECYRDT	Year And Date Of Record - 2 Most Sig. Digits = Year - 3 Least Sig. Digits = Julian Date
3	ACFTN	Aircraft Tail Number
4	FLTNO	Aircraft Sortie Number
5	DDUYRDT	Year And Date Of Data Collection - 2 Most Sig. Digits = Year - 3 Least Sig. Digits = Julian Date
6	DDUTM	Time Of Data Collection (Military Hours And Minutes)
7	GLBSCID	Global Data Block ID Flag/Scan Counter = 0 For Global Block = 1 -18 For Stored Data Blocks Corresponding To Data Scans 1-18

NOTE: All Words Are Integers

TABLE 19. AUTOMATIC TAKEOFF RECORD FILE STORED DATA RECORD DESCRIPTION

WORD(S)	SYMBOL	DESCRIPTION	UNITS
1-35	-------SAME AS TABLE 16 ------------------------		
36	ANTIC	Anti-Ice Discreet (1.0=ON)	
37-45	-------SAME AS TABLE 16 ------------------------		

TABLE 20. MCAIR AUTOMATED EDS MAINTENANCE RECORD FILE DESCRIPTION ON EQUIPMENT (AIRCRAFT OR ENGINE) RECORD

Character(s)	Description
1-7	Job Control Number (JCN)
8-10	AFTO 349 Form Number (MCAIR Assigned Number)
11-15	Performing Work Center
16-19	Identification Number
20-24	Aircraft Time (Tenths Of Hours)
25-27	AFTO 350 Tag Number
28	Type Maintenance Code (See T.O. 1F-15A-06)
29	Component Position Code (1=Left; 2=Right)
30-34	Work Unit Code (See T.O. 1F-15A-06)
35	Action Taken Code (See T.O. 1F-15A-06)
36	When Discovered Code (See T.O. 1F-15A-06)
37-39	How Malfunctioned Code (See T.O. 1F-15A-06)
40-41	Number of Units Produced
42-45	Start Time (Military)
46-48	Stop Date (Julian)
49-52	Stop Time (Military)
53	Crew Size
54	Category Of Labor
55-60	Fuel Consumed (pounds)
61-77	Blank
78-79	Sequence Number (01-05 For On-Aircraft; 06-10 For On-Engine)
80	Card Code ("A" For On-Aircraft; "E" For On-Engine)

TABLE 20 (Continued). MCAIR AUTOMATED EDS MAINTENANCE RECORD DESCRIPTION
OFF-EQUIPMENT RECORD

Character(s)	Description
1-7	Job Control Number (JCN)
8-10	AFTO 349 Form Number (MCAIR Assigned Number)
11-15	Performing Work Center
16-19	Identification Number
20-23	Federal Stock Classification
24-38	Part Number
39-43	Serial Number
44-46	AFTO 350 Tag Number
47	Type Maintenance Code (See T.O. 1F-15A-06)
48	Component Position Code (1=Left; 2=Right)
49-53	Work Unit Code (See T.O. 1F-15A-06)
54	Action Taken Code (See T.O. 1F-15A-06)
55	When Discovered Code (See T.O. 1F-15A-06)
56-58	How Malfunction Code (See T.O. 1F-15A-06)
59-60	Number Of Units Produced
61-64	Start Time (Military)
65-67	Stop Date (Julian)
68-71	Stop Time (Military)
72	Crew Size
73	Category Of Labor
74-77	Blank
78-79	Sequence Number (11-15 For Off-Equipment Record)
80	Card Code ("H" For Off-Equipment Record)

TABLE 20 (Continued). MCAIR AUTOMATED EDS MAINTENANCE RECORD FILE DESCRIPTION REMOVAL OF SERIALIZED COMPONENT RECORD

Character(s)	Description
1-7	Job Control Number (JCN)
8-10	AFTO 349 Form Number (MCAIR Assigned Number)
11-15	Performing Work Center
16-19	Identification Number
20-23	Federal Stock Classification
24-38	Part Number
39-47	Serial Number
48-50	AFTO 350 Tag Number
51	Type Maintenance Code (See T.O. 1F-15A-06)
52	Component Position Code (1=Left; 2=Right)
53-57	Work Unit Code (See T.O. 1F-15A-06)
58	Action Taken Code (See T.O. 1F-15A-06)
59	When Discovered Code (See T.O. 1F-15A-06)
60-62	How Malfunction Code (See T.O. 1F-15A-06)
63-64	Number of Units Produced
65-68	Start Time (Military)
69-71	Stop Date (Julian)
72-75	Stop Time (Military)
76	Crew Size
77	Category Of Labor
78-79	Sequence Number (16-20 For Removal Of Serialized Component)
80	Card Code ("R" For Removal And Installation of Serialized Component Record)

TABLE 20 (Continued). MCAIR AUTOMATED EDS MAINTENANCE RECORD FILE DESCRIPTION
INSTALLATION OF SERIALIZED COMPONENT RECORD

Character(s)	Description
1-7	Job Control Number (JCN)
8-10	AFTO 349 Form Number (MCAIR Assigned Number)
11-15	Performing Work Center
16-19	Identification Number
20-22	AFTO 350 Tag Number
23-37	Part Number
38-46	Serial Number
47-50	Operating Time Of Component (Tenths Of Hours)
51	Type Maintenance Code (See T.O. 1F-15A-06)
52	Component Position Code (1=Left; 2=Right)
53-57	Work Unit Code (See T.O. 1F-15A-06)
58	Action Taken Code (See T.O. 1F-15A-06)
59	When Discovered Code (See T.O. 1F-15A-06)
60-62	How Malfunction Code (See T.O. 1F-15A-06)
63-64	Number Of Units Produced
65-68	Start Time (Military)
69-71	Stop Date (Julian)
72-75	Stop Time (Military)
76	Crew Size
77	Category Of Labor
78-79	Sequence Number (21-25 For Installation Of Serialized Component)
80	Card Code ("R" For Removal And Installation Of Serialized Component Record)

TABLE 20 (Continued). MCAIR AUTOMATED EDS MAINTENANCE RECORD FILE DESCRIPTION
REMOVAL/INSTALLATION OF AIRCRAFT ENGINE RE D

Character(s)	Description
1-7	Job Control Number (JCN)
8-10	AFTO 349 Form Number (MCAIR Assigned Number)
11-15	Performing Work Center
16-19	Aircraft Identification Number
20-24	Aircraft Time (Tenths Of Hours)
25-29	Removed Engine Time (Tenths Of Hours)
30-33	Removed Engine Identification Number
34-38	Installed Engine Time (Tenths Of Hours)
39-42	Installed Engine Identification Number
43-45	AFTO 350 Tag Number
46	Type Maintenance Code (See T.O. 1F-15A-06)
47	Component Position Code (1=Left; 2=Right)
48-52	Work Unit Code (See T.O. 1F-15A-06)
53	Action Taken Code (See T.O. 1F-15A-06)
54	When Discovered Code (See T.O. 1F-15A-06)
55-57	How Malfunction Code (See T.O. 1F-15A-06)
58-59	Number Of Units Produced
60-63	Start Time (Military)
64-66	Stop Date (Julian)
67-70	Stop Time (Military)
71	Crew Size
72	Category Of Labor
73-77	Blank
78-79	Sequence Number (26-35 For Removal/Installation Of Aircraft Engine)
80	Card Code ("T" For Removal/Installation Of Aircraft Engine Record)

TABLE 20 (Continued). MCAIR AUTOMATED EDS MAINTENANCE RECORD FILE DESCRIPTION
DISCREPANCY/CORRECTIVE ACTION RECORD

Character(s)	Description
1-7	Job Control Number (JCN)
8-10	AFTO 349 Form Number (MCAIR Assigned Number)
11-77	Write-Up Of Discrepancy/Corrective Action Taken Directly From AFTO 349
78-79	Sequence Number (36-45 For Discrepancy/Corrective Action Record)
80	Card Code (Matches The Card Code Of The Record To Which The Discrepancy/Corrective Action Write-Up Applies)

TABLE 20(Concluded). MCAIR AUTOMATED EDS MAINTENANCE RECORD FILE DESCRIPTION
PARTS REPLACED DURING REPAIR RECORD

Character(s)	Description
1-7	Job Control Number (JCN)
8-10	AFTO 349 Form Number (MCAIR Assigned Number)
11	Line Number
12-15	Federal Stock Classification
16-30	Part Number
31-35	Work Unit Code (See T.O. 1F-15A-06)
36-44	Reference Symbol (Part Description)
45-47	How Malfunction Code (See T.O. 1F-15A-06)
48-49	Quantity Of Parts Replaced
50-77	Blank
78-79	Sequence Number (46-60 For Parts Replaced During Repair Record)
80	Card Code ("P" For Parts Replaced During Repair Record)

3. SUMMARY OF TRANSMITTALS - Sixteen EDS data transmittals were made during the Advanced Trend Analysis Program. These transmittals are summarized in Table 21. Each transmittal potentially consisted of three types of data files; the EDS Recorded Data File, the MCAIR Automated EDS Maintenance Record File, and the Automatic Takeoff Record File. The content and format of each of these files was discussed in Section III.2. Note that Transmittal Numbers 1 through 9 were made on an approximate monthly basis while Transmittal Numbers 10 through 16 were made on an approximate bi-weekly basis. This increased data transmittal rate reduced the time lag experienced between the recording of the data at Langley and its availability for analysis in the AFWAL/SCT data base at WPAFB. These sixteen transmittals contained nearly 1200 records as shown in Table 22, by transmittal number, and in Table 23 by engine serial number. Four record types were transmitted; usage records, Trend records, Performance Check records, and Automatic Takeoff records. Usage records contain only engine time and cycle information and represent data transfers that did not contain Trend/Performance Check/Takeoff records. The remaining three record types were discussed in Section II. Detailed logs of all the data entries that comprise these sixteen EDS data transmittals are given in Appendix B.

TABLE 21. EDS DATA TRANSMITTAL SUMMARY

TRANS. NO.	PERIOD COVERED	DATE TRANS.	EDS DATA FILE	MAINT. RCD. FILE	TAKEOFF FILES (NO.)
1	4/16-5/15/80	6/30/80	YES*	NO	NO
2	5/16-6/15/80	7/24/80	YES*	NO	NO
3	6/16-7/15/80	8/14/80	YES*	YES	NO
4	7/16-8/7/80	9/29/80	YES	YES	NO
5	8/8-9/15/80	10/28/80	YES	YES	NO
6	9/16-10/31/80	12/3/80	YES	YES	NO
7	11/1-12/11/80	1/9/81	YES	NO	NO
8	12/12/80-1/31/81	3/3/81	YES	NO	NO
9	2/1-3/13/81	3/27/81	YES	NO	NO
10	3/14-3/31/81	4/22/81	YES	NO	YES (1)
11	4/1-4/15/81	4/29/81	YES	NO	YES (1)
12	4/16-4/30/81	5/13/81	YES	NO	YES (1)
13	5/1-5/15/81	5/23/81	YES	NO	YES (3)
14	5/16-5/31/81	6/9/81	YES	NO	YES (2)
15	6/1-6/12/81	6/22/81	YES	NO	YES (2)
16	6/13-6/28/81	7/10/81	YES**	NO	YES (1)**

* Contained Entries For Only Those Data Transfers With A Trend And/Or Performance Check Record.

** All Data Obtained After 16 June Was Lost Because Of A Problem With The EDS AGP.

TABLE 22. RECORD TRANSMITTAL SUMMARY BY TRANSMITTAL NUMBER

TRANS. NO.	USAGE RECORDS	TREND RECORDS	PERF. CHK. RECORDS	TAKEOFF RECORDS
1	0	20	3	0
2	0	14	2	0
3	0	10	2	0
4	73	27	13	0
5	77	23	17	0
6	114	53	12	0
7	68	36	18	0
8	29	5	2	0
9	49	0	7	0
10	13	0	1	16
11	4	20	26	40
12	6	33	40	48
13	9	36	31	41
14	9	28	20	28
15	13	14	11	16
16	0	2	2	4
	464	321	207	193

TOTAL RECORDS = 1185

TABLE 23. RECORD TRANSMITTAL SUMMARY
By Engine Serial Number

ENGINE S/N	USAGE RECORDS	TREND RECORDS	PERF. CHK. RECORDS	TAKEOFF RECORDS
P680160	46	22	9	18
P680311	29	24	11	7
P680330	65	37	31	17
P680415	50	35	24	24
P680470	44	34	30	36
P680528	34	25	17	19
P680639	26	25	7	0
P680694	44	42	24	11
P680722	31	18	12	0
P680801	40	26	26	24
P680907	55	33	16	37
	464	321	207	193

TOTAL RECORDS = 1185

SECTION IV

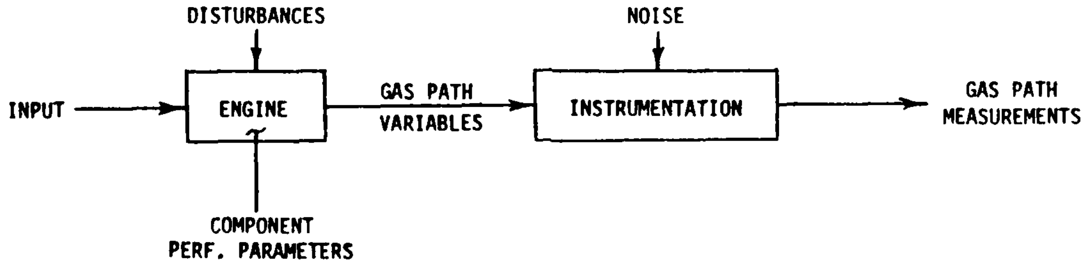
ASSESSMENT OF SCT'S GAS PATH ANALYSIS ALGORITHM

An important objective of the Advanced Trend Analysis Program was to assess the potential usefulness of SCT's gas path analysis algorithm as a diagnostic/prognostic tool for engine maintenance. The database of F100 engine trending records provided by the EDS Flight Evaluation was to allow a "real world" test of the algorithm's capabilities. Because of the trending data acquisition problems experienced during the Flight Evaluation (see Section II.3.b), an adequate database for testing the algorithm could not be built. Therefore, a definite conclusion as to the usefulness of the algorithm cannot be made with the Advanced Trend Analysis Program database. For purposes of documentation, the following sections provide a brief description of the algorithm and discuss the results of applying the algorithm to the Advanced Trend Analysis Program database.

1. <u>ALGORITHM DESCRIPTION</u> - A discussion of any gas path analysis algorithm used for gas turbine engine health trending should begin with a statement of the problem. Figure 23 schematically shows the engine and instrumentation that generate the measurands used by the trending algorithm. The engine, with unknown component performance parameters (low pressure compressor efficiency and flow capacity, high pressure compressor efficiency and flow capacity, etc.), operates at a point determined by the inputs (power setting and flight conditions) and random disturbance effects (mechanical hysteresis, bleed, engine nonequilibrium, etc.). The resulting gas path variables (rotor speeds, temperatures, and pressures) are measured with imperfect instruments contaminated with noise. The trending problem, then, is to accurately determine the health status of the engine, in other words the current values of the various component performance parameters, using imperfect, noisy measurements of variables that are, at best, only functions of the unknown component performance parameters knowing that the engine is subject to random disturbance effects. SCT's approach to this problem is categorized as Thermodynamic Cycle Monitoring (TCM). This approach employs a maximum likelihood parameter estimator which analytically relates variations in the gas path variables to changes in the engine component performance parameters and statistically accounts for the noise and random disturbance effects. Figure 24 shows the pertinent input, disturbance, and gas path measurands along with the various component efficiencies (η) and flow capacities (Γ). The following paragraphs give a brief description of SCT's gas path analysis algorithm. For a detailed discussion of the algorithm and its underlying theory, the reader is directed to SCT's Turbine Engine Fault Detection and Isolation (TEFDI) Program Final Report scheduled for release in early 1982.

SCT's algorithm consists of four software modules. These modules are shown schematically in Figure 25. Raw EDS trending data, obtained during a fixed duration operating time window, is input to the Sensor Diagnostic Routine where both hard and intermediate sensor failures are detected and isolated. Synthesized data is generated for those channels determined to be failed. This processed data is input to the Health Index Estimation Routine where a "maximum likelihood" estimate of the engine health status is made.

SYSTEM MODEL:



PROBLEM: *ACCURATELY ESTIMATE ENGINE HEALTH (i.e. COMPONENT PERF. PARAMETERS)*

- NOISE IN MEASUREMENTS
- MEASURED VARIABLES ONLY FUNCTIONS OF PERF. PARAMETERS
- RANDOM DISTURBANCES

APPROACH: THERMODYMIC CYCLE MONITORING (TCM)

- MAXIMUM LIKELIHOOD PARAMETER ESTIMATION
    - o ANALYTICALLY RELATE VARIABLES AND PERF. PARAMETERS
    - o STATISTICALLY ACCOUNT FOR NOISE AND DISTURBANCES

Figure 23. Statement of Trending Problem

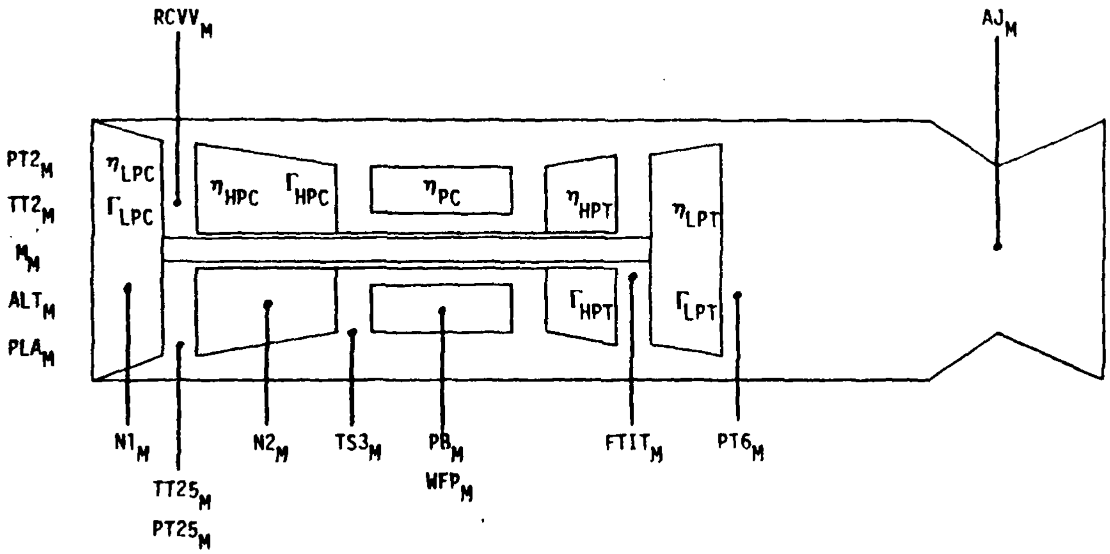


Figure 24. Pertinent Measurands and Component Performance Parameters

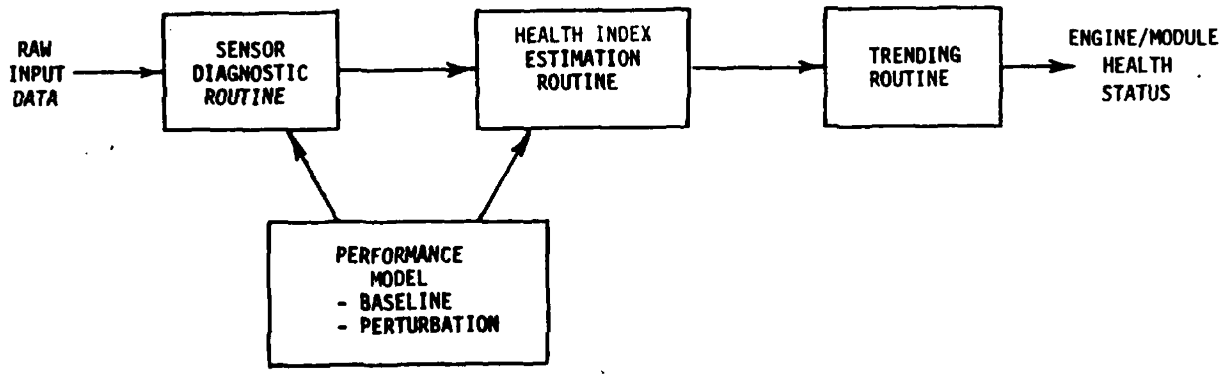
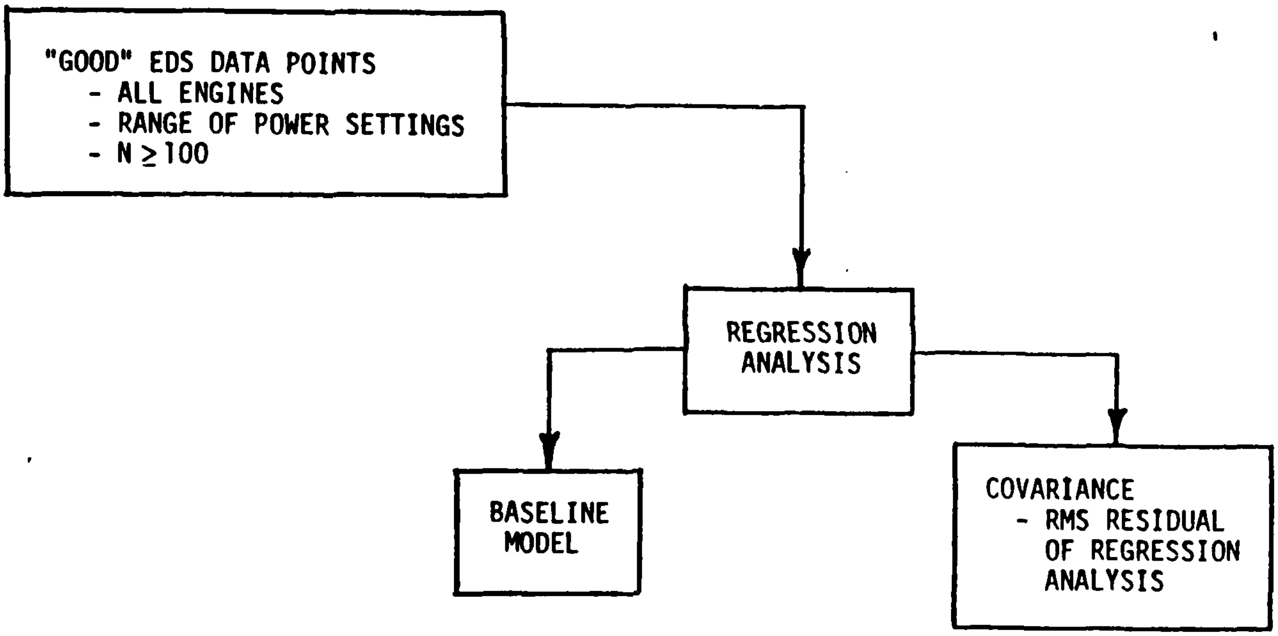


Figure 25. Algorithm Structure

Both the Sensor Diagnostic Routine and the Health Index Estimation Routine employ the F100 Performance Model to determine baseline (i.e. unperturbed) engine performance and engine sensitivities to off-nominal perturbations as a function of engine operating point. The current engine health index estimates are then input to the Trending Routine where they are analyzed with respect to previous estimates for statistically significant changes.

The F100 Performance Model consists of 2 elements; the baseline model and the perturbation model. The development of the baseline model is shown schematically in Figure 26. A set of "good" EDS measured data points is input to a regression analysis procedure which yields mathematical expressions for the gas path variables, in terms of the other variables, as a function of engine operating point. "Good" data points are those that have no detectable failed data channels. The number of "good" data points used for this process should be greater than 100 so that a statistically valid representation of the "nominal EDS engine" is obtained. In addition to the regressed expressions for each gas path variable, the covariance of the model (i.e. the RMS residuals of the regression analyses) is computed. An example baseline equation and its associated covariance element is given in Figure 26. The development of the perturbation model is shown schematically in Figure 27. Perturbed component performance parameters and engine disturbances are force fed into a Pratt and Whitney Aircraft (PWA) F100 Engine Simulation Deck (ESD) to generate the sensitivities of the gas path variables to these perturbations/disturbances. This is done over a range of engine power settings and flight conditions. The sensitivity results are then regressed to determine expressions relating changes in the gas path variables to component performance parameter perturbations and disturbance effects. An example perturbation model expression is given in Figure 27. SCT employs a memory efficient structure for both the baseline and perturbation models. This structure consists of a coefficient vector, a variable/parameter vector, and a closely packed exponent matrix. This structure not only reduces the computer core requirements of the model but also simplifies derivative and gradient calculations required by the Health Index Estimation Routine.

The Sensor Diagnostic Routine employs the baseline portion of the F100 Performance Model. Both the regressed baseline model gas path variable expressions and the model covariance are used. A flowchart of the Sensor Diagnostic Routine is shown in Figure 28. This flowchart is greatly oversimplified but does serve to illustrate how failed data channels are detected and isolated. For a given data point the differences between the gas path measurements and the baseline model, at the measured engine operating point, are calculated. The set of out-of-range differences is statistically determined using the baseline model covariance elements. The baseline model is then used to synthesize values for those out-of-range channels. A new set of differences is computed using the synthesized data values in place of the suspected failed channels and a new set of out-of-range differences is determined. This new set is compared with the old set and the procedure either stops, if the two sets are the same, or continues to synthesize values for suspect failed data channels and calculate new sets of out-of-range differences until convergence is obtained. The dominant feature of this procedure is its ability to synthesize values for the failed data channels. This feature significantly enhances the usefulness of "real world" data where failed sensors are commonplace.

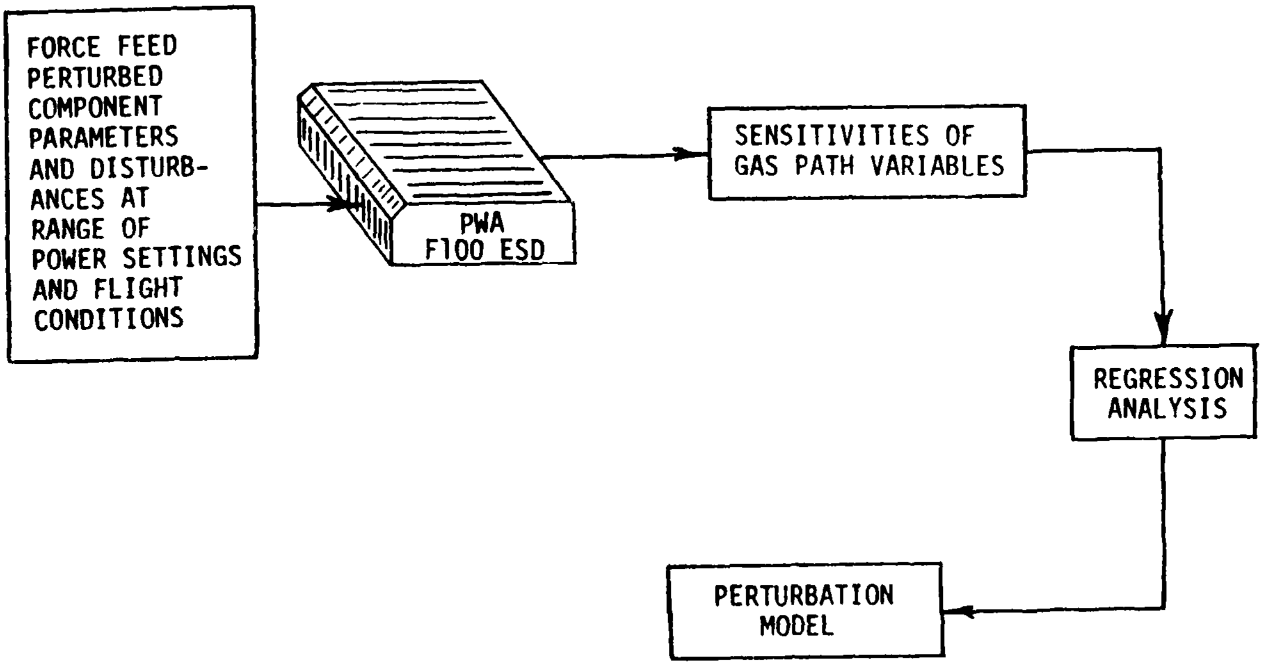


EXAMPLE:

$$TT25_{B/L} = (.02987)N1-(22.77)AJ+(.7616)TT2-102.6$$

$$\sigma_{TT25} = 1.5°C$$

Figure 26. Baseline Model Development



EXAMPLE:

$$\Delta TT25 = -(.3985)(FTIT)\,\Delta\eta_{LPC} + (144.4)\,\Delta\Gamma_{LPC} - (.004043)(N2)\,\Delta\eta_{HPC}$$
$$-(61.5)\,\Delta\eta_{LPT} - (30.31)\,\Delta\Gamma_{LPT} - (.01362)(FTIT)\,\Delta AJ$$

WHERE

$$\frac{\partial TT25}{\partial \eta_{LPC}} = -(.3985)(FTIT) \quad ;ETC$$

Figure 27. Perturbation Model Development

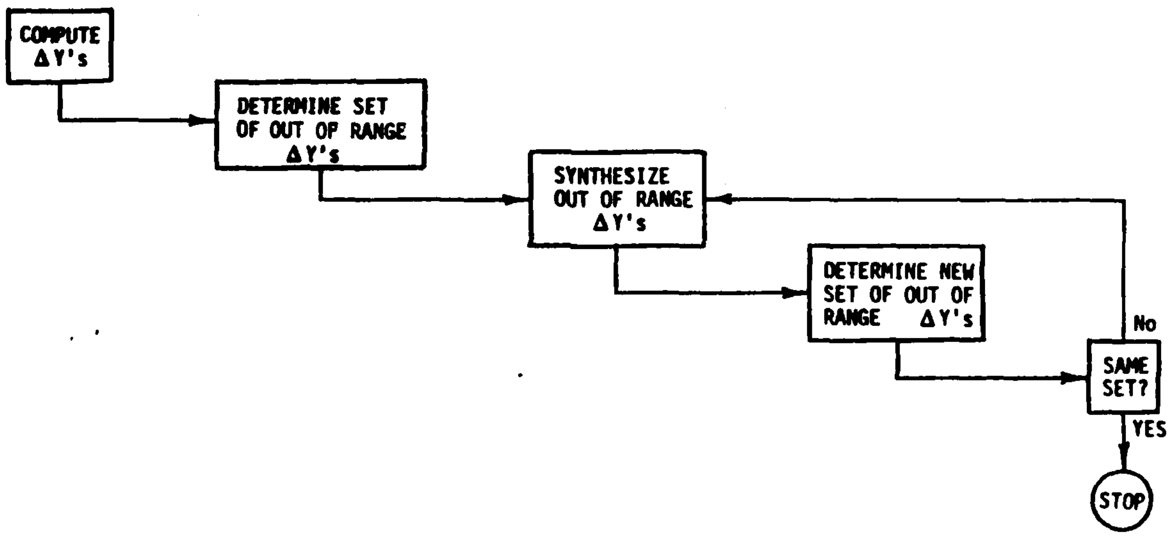


Figure 28. Sensor Diagnostic Routine

Three module directed health indices are estimated by the Health Index Estimation Routine. Not all of the component performance parameters shown in Figure 24 can be accurately estimated. The maximum number of parameters that can be accurately estimated and their form are determined by the number and accuracy of the gas path measurements available. For the F100 EDS instrumentation, the maximum number of parameters, or indices, that can be estimated is three. The form of these indices is somewhat arbitrary but SCT determined the three module directed indices defined in Figure 29 to be optimum in terms of usefulness and accuracy. As can be seen, the fan, core, and high pressure turbine (HPT) indices are linear combinations of pertinent fundamental component performance parameters. As shown schematically in Figure 30, the module directed health indices are estimated using the processed data output from the Sensor Diagnostic Routine with a Kalman filter. This filter assumes the engine performance varies linearly with component deterioration and disturbance effects in a small region about a nominal baseline operating point. Within a fixed duration incremental engine operating time window, multiple measured data points are sequentially processed by the filter to produce weighted least squares estimates of the module directed health indices. This filtering of the measured data reduces the impact of measurement error, measurement noise, and disturbance effects on the index estimates. The uncertainty level associated with each index is also computed by the filter. This uncertainty level is directly affected by the number of measured data points that were available in a given time window. This effect is illustrated in Figure 30 where the maximum likelihood estimate of the health index is shown with its associated 95% confidence interval. Note that the uncertainty level associated with each index estimate, i.e. the size of the confidence internal, is inversely related to the number of measured data points that were filtered into it. It is for this reason that a relatively high trending data acquisition rate is critical to the successful implementation of SCT's algorithm. The higher the data acquisition rate, the more measured data points will be available in each operating time window and the more certain will be each health index estimate.

A general purpose Trending Routine is the final step in the algorithm. This routine statistically determines whether a new health index estimate is part of a continuing trend, established by previous estimates, or represents a "jump" in the data, signalling the start of a new trend. Both the value and uncertainty of the new estimate, relative to the previous estimates, is considered by this routine. Although this routine processes the estimates in a purely mathematical manner, there should be some physical explanation for the trends and "jumps" it detects. For example, a "jump" should correlate with an engine module change, FOD occurance, or engine water wash. Engine trim or control component changes should not show up as "jumps" since they do not affect the fundamental engine component performance parameters.

2. <u>DISCUSSION OF RESULTS</u> - The results of applying SCT's gas path analysis algorithm to the Advanced Trend Analysis Program database are inconclusive. An insufficient amount of trending data was acquired early in the EDS Flight Evaluation to validate SCT's algorithm. Late in the evaluation, an acceptable trending data acquisition rate was achieved. However, during this roughly three month period, no major maintenance actions were required on the EDS engines. For true validation of the algorithm, a combination of a high data acquisition rate and significant maintenance actions (module

$$\theta_{FAN} = (.57)\Delta\eta_{LPC} + (.82)\Delta\Gamma_{LPC}$$

$$\theta_{CORE} = (.56)\Delta\eta_{HPC} + (.59)\Delta\Gamma_{HPC} + (.58)\Delta\eta_{PC}$$

$$\theta_{HPT} = (.88)\Delta\eta_{HPT} - (.48)\Delta\Gamma_{HPT}$$

Figure 29. Module Directed Health Indices

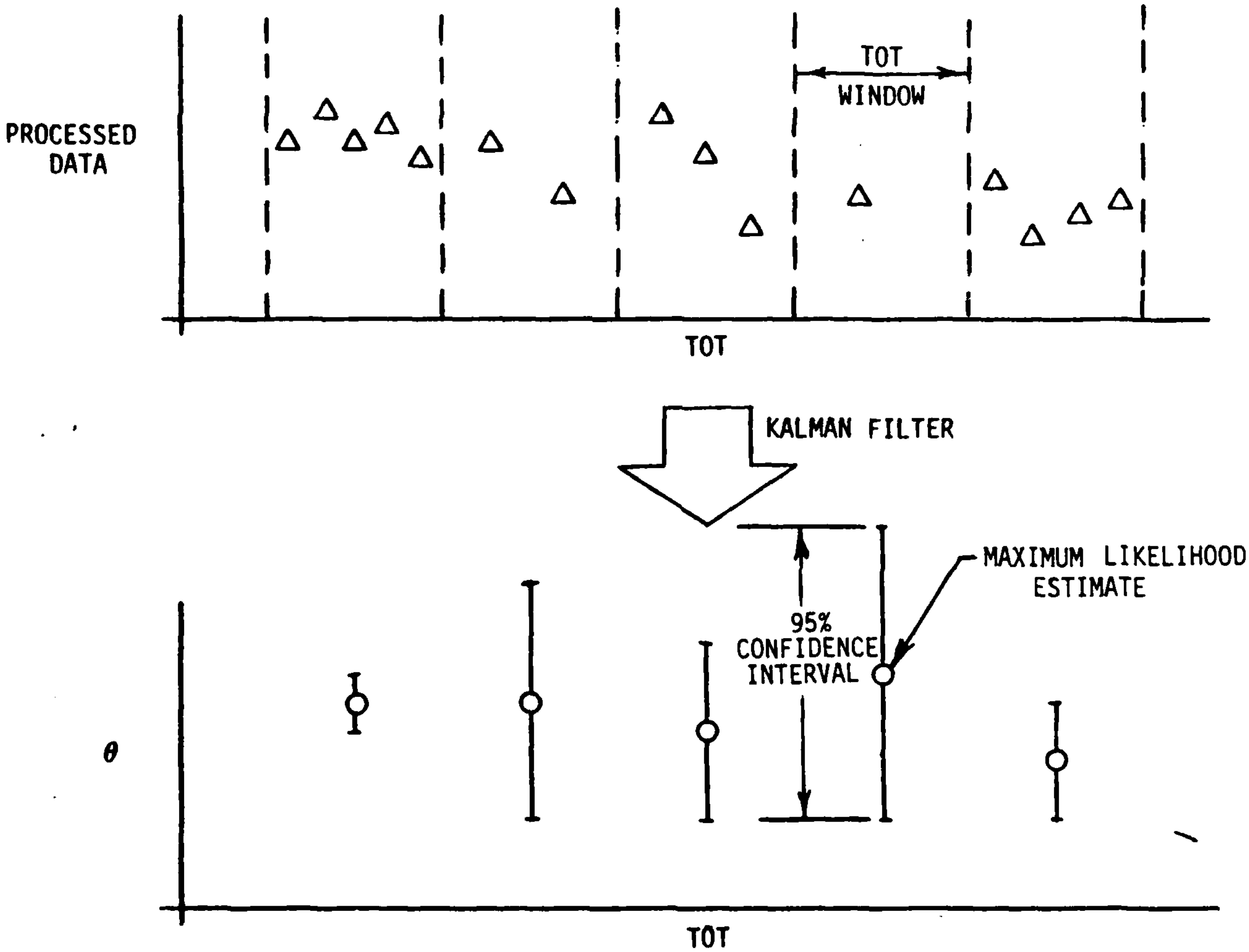


Figure 30. Estimation Routine

change, significant FOD, etc.) must occur. The following paragraphs discuss the results obtained with particular emphasis on the last three months of the Flight Evaluation when an acceptable trending data acquisition rate was achieved.

An insufficient amount of trending data was acquired during the first year of the EDS Flight Evaluation to validate SCT's algorithm. As discussed in Section II.3.b, a trending data acquisition rate of 10 per 100 EOH was experienced during the first 9 months and a rate of 2 per 100 EOH was experienced during the next three months. These rates are extremely low when compared to the A-10/TF34 TEMS rate of 35 per 100 EOH for which SCT demonstrated some promising results with their algorithm. The most conclusive long term trending results are shown in Figure 31 for engine S/N 694. As can be seen, a fan module change was made at 1200 hours TOT. A relative increase in the level of the Fan Health Index should reflect this module change. While it is true that the general level of the five data points after the module change is relatively higher than the one point before the module change, this is hardly conclusive evidence that the algorithm accurately represented the module change. What is needed, of course, is more data in the pre-module change period. Unfortunately, this period coincides with the low data acquisition rate period. It should be emphasized that this represents the most conclusive long term trending results available from the Advanced Trend Analysis Program database.

Promising, although still inconclusive, short term trending results were obtained by applying SCT's algorithm to the final three months of data. During this period, an acceptable trending data acquisition rate was achieved with Trend and Performance Check Software Configuration Numbers 3 and 4 (see Section II). Table 24 summarizes the operating time accumulated, the number of Trend and Performance Check records transmitted, and the trending data acquisition rate experienced during this period for the EDS engines that were still involved in the program. As mentioned previously, there were no major maintenance actions performed on these engines during this time. Therefore, no conclusive analysis of the trending results can be made. However, the trends of the three estimated module health indices can be checked to determine if the algorithm produced reasonable results during this period. In this case, reasonable results would be a slight decreasing trend or no trend at all in the three indices. This would represent slight, or no, module deterioration. These short term results are presented for all of the engines, except three, in Figures 32 through 37. The three engines not represented in these figures are serial numbers 160, 311, and 907. The short term trending results for serial numbers 160 and 311 are not presented because only three valid data points were available during this period. The results for serial number 907 are not presented because the data for this engine was, for some unknown reason, not in the SCT database. As can be seen from the figures, for all engines except engine serial number 528, reasonable module health index trends were obtained. The core module index on engine serial number 528 shows a slight positive trend representing an improvement in the module health. However, the slope of this trend is extremely small and is not significant in light of the number of data points. These promising short term trending results should not be

ENGINE S/N 694

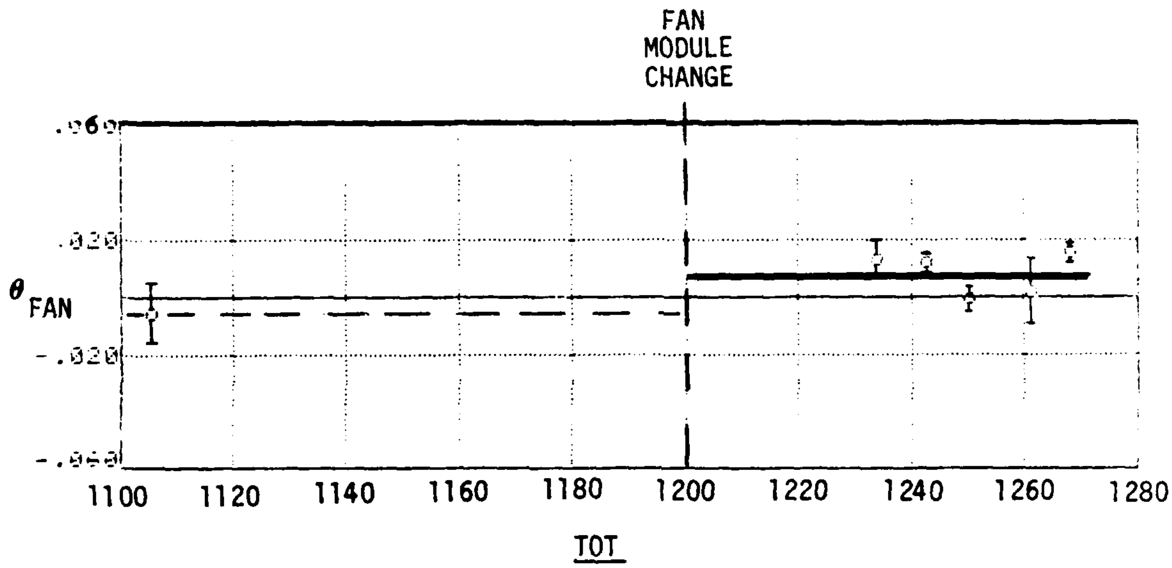


Figure 31. Long Term Trending Results

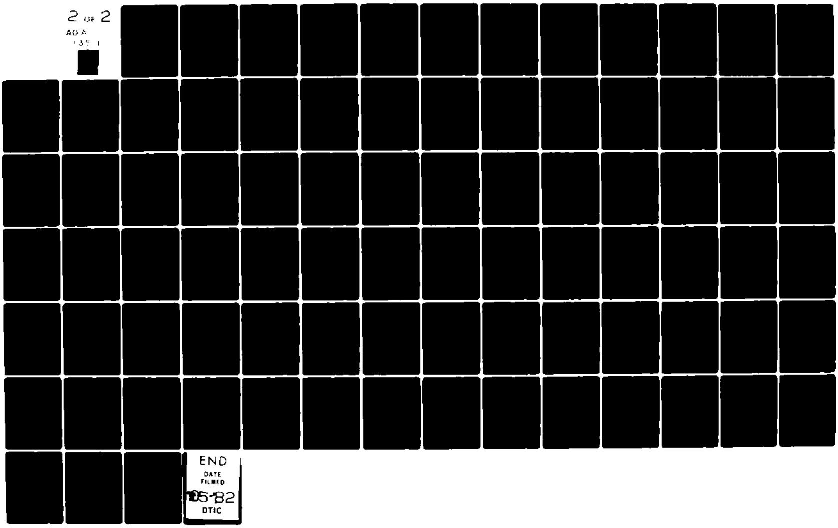
TABLE 24. OPERATING TIME AND DATA ACQUISITION RATE SUMMARY
Software Configuration Numbers 3 and 4

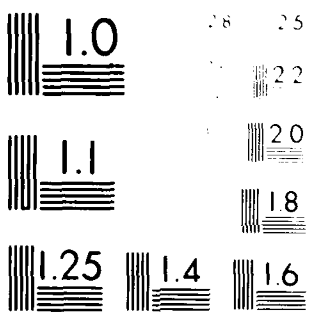
ENGINE S/N	TOT*	TOT	NO. OF RECORDS** TREND	PERF CHECK	RATE** (PER 100 EOH)
160	1567.8	96.9	6	5	11.35
311	1519.1	56.7	9	8	29.98
330	1316.3	53.3	8	12	37.52
415	868.1	106.2	21	19	37.66
470	772.3	91.3	17	25	46.00
528	1080.4	74.0	15	13	37.84
694	1230.0	41.3	14	12	62.95
801	1154.4	98.0	19	21	40.82
907	935.5	130.3	20	13	25.33
		748.0	129	128	

* When Configuration No. 3 Was First Implemented.
** Includes Only Those Records Transmitted To WPAFB.

AD-A113 511 MCDONNELL AIRCRAFT CO ST LOUIS MO F/G 9/2
ADVANCED TRENDING ANALYSIS/EDS DATA PROGRAM.(U)
JAN 82 D C PERRYMAN F33615-78-C-2070
UNCLASSIFIED AFWAL-TR-81-2125 NL

2 OF 2
AD A
113511




1.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

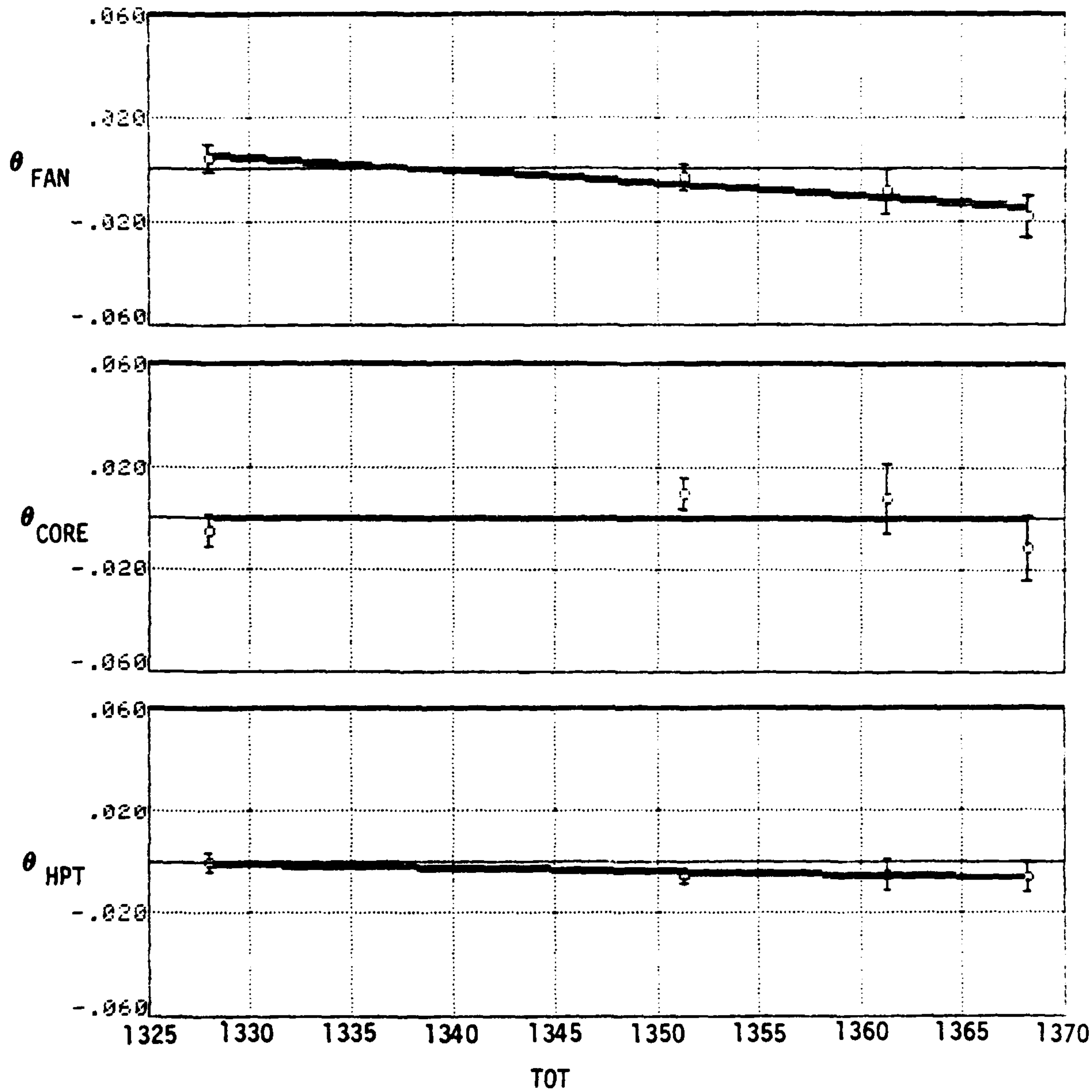


Figure 32. Short Term Trending Results
Engine S/N 330

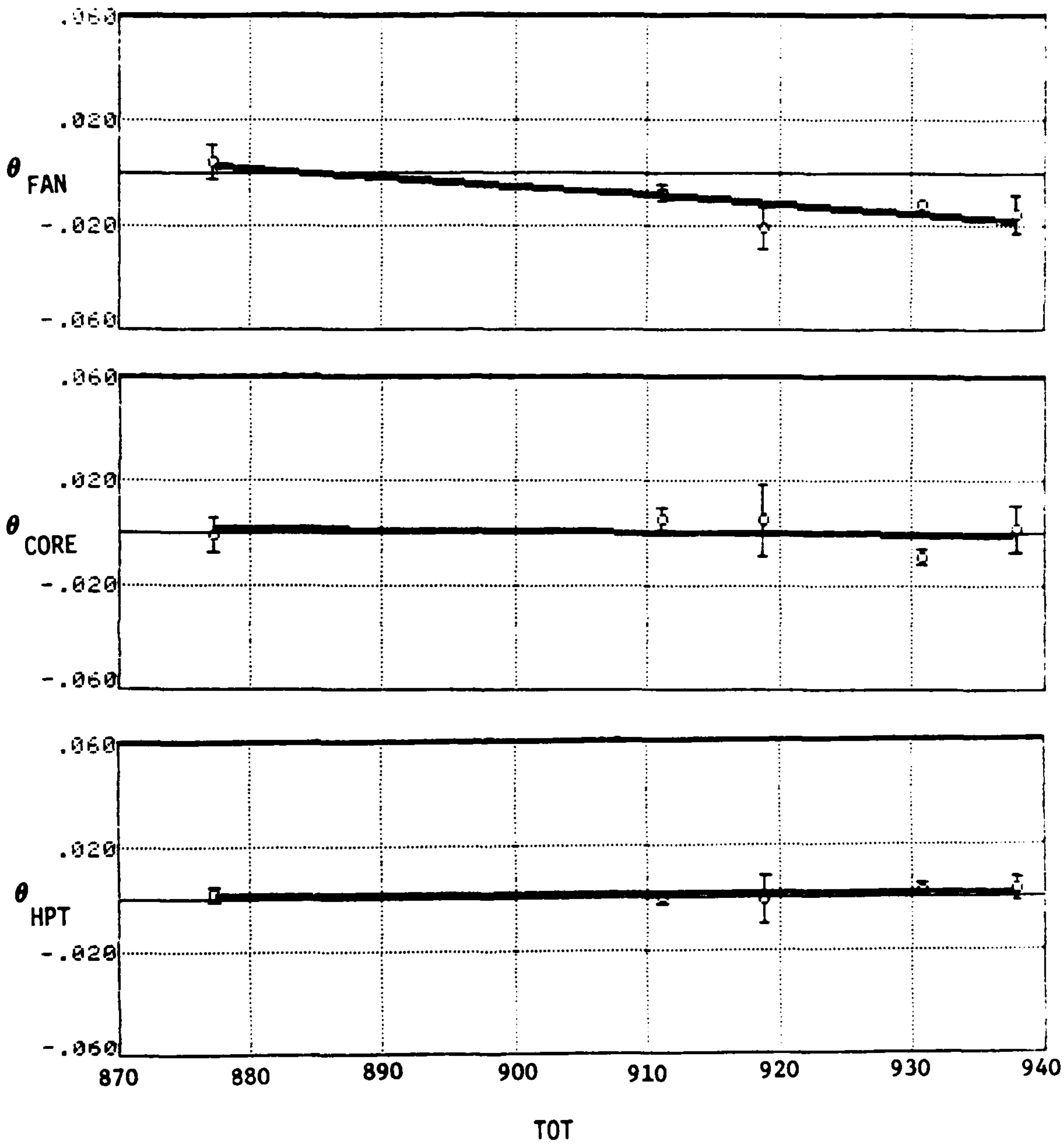


Figure 33. Short Term Trending Results
Engine S/N 415

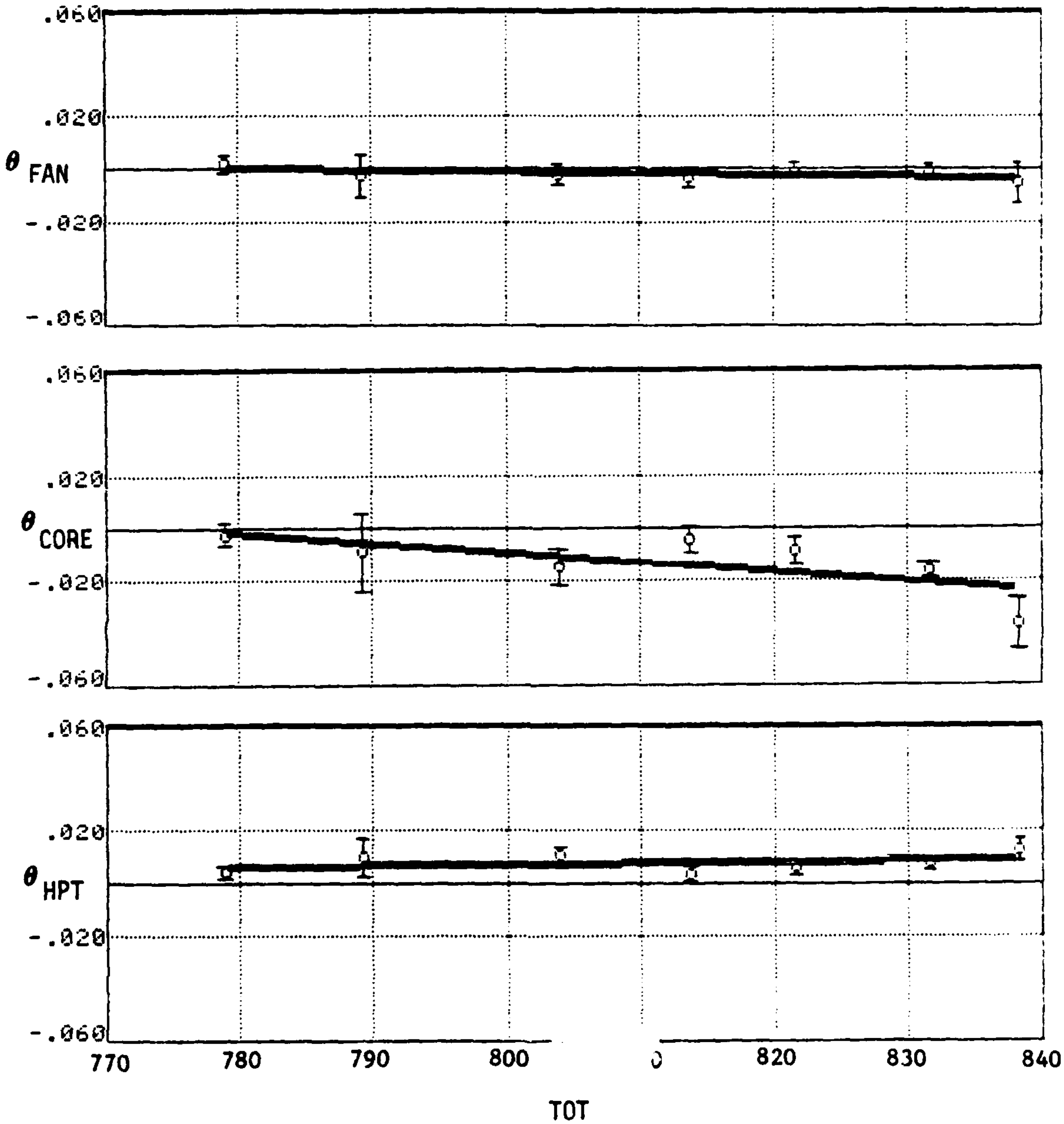


Figure 34. Short Term Trending Results
Engine S/N 470

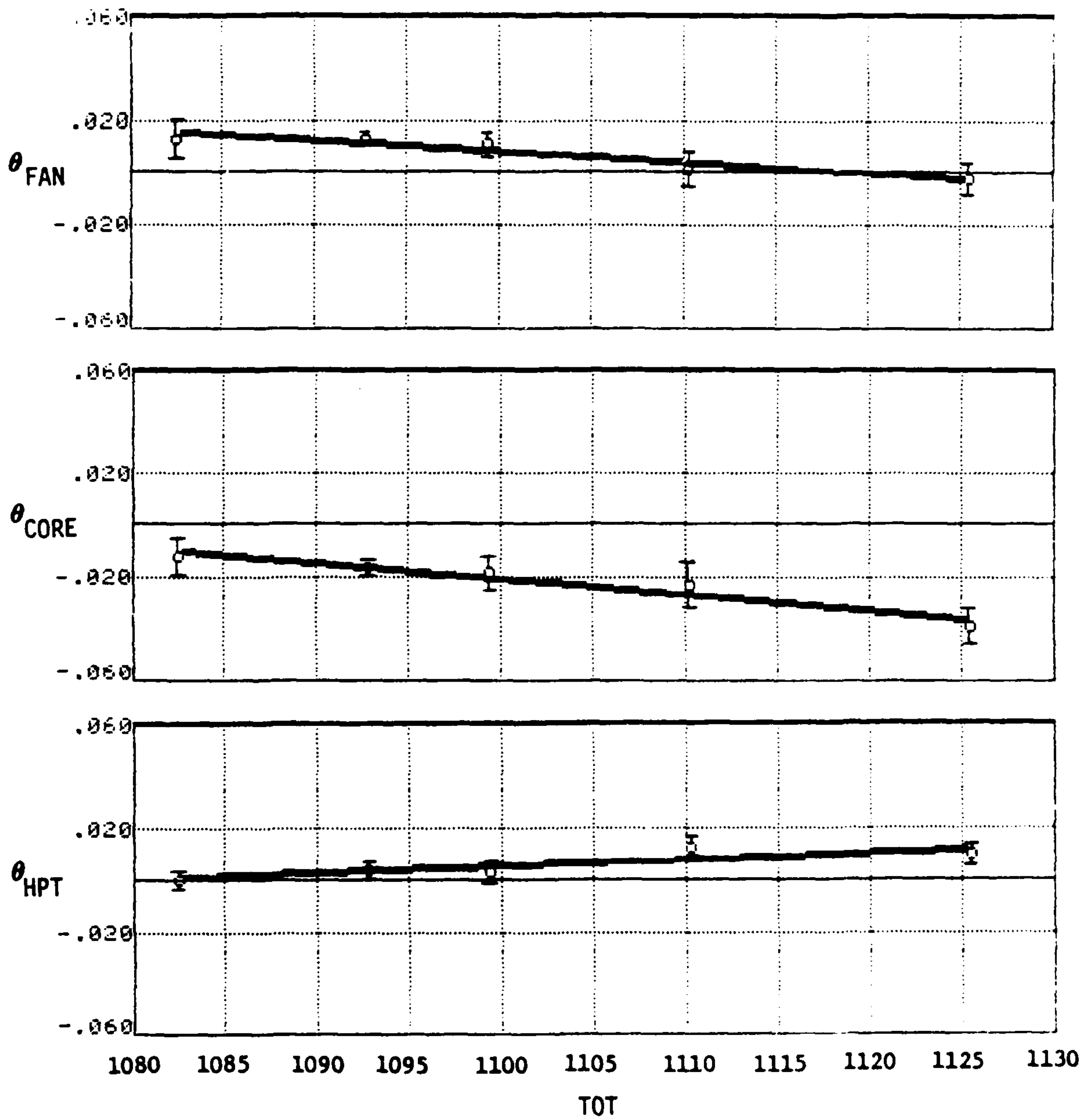


Figure 35. Short Term Trending Results
Engine S/N 528

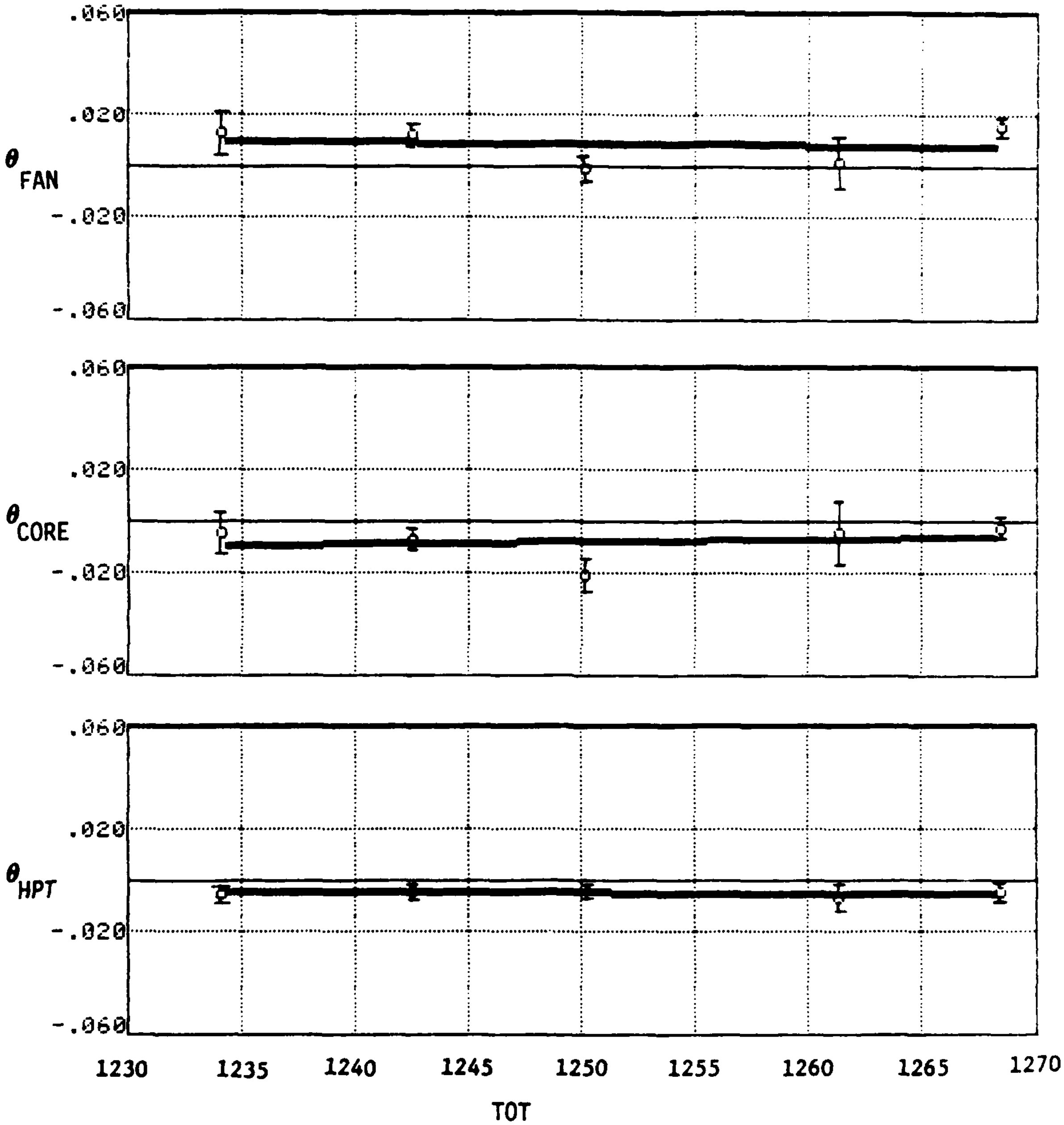


Figure 36. Short Term Trending Results
Engine S/N 694

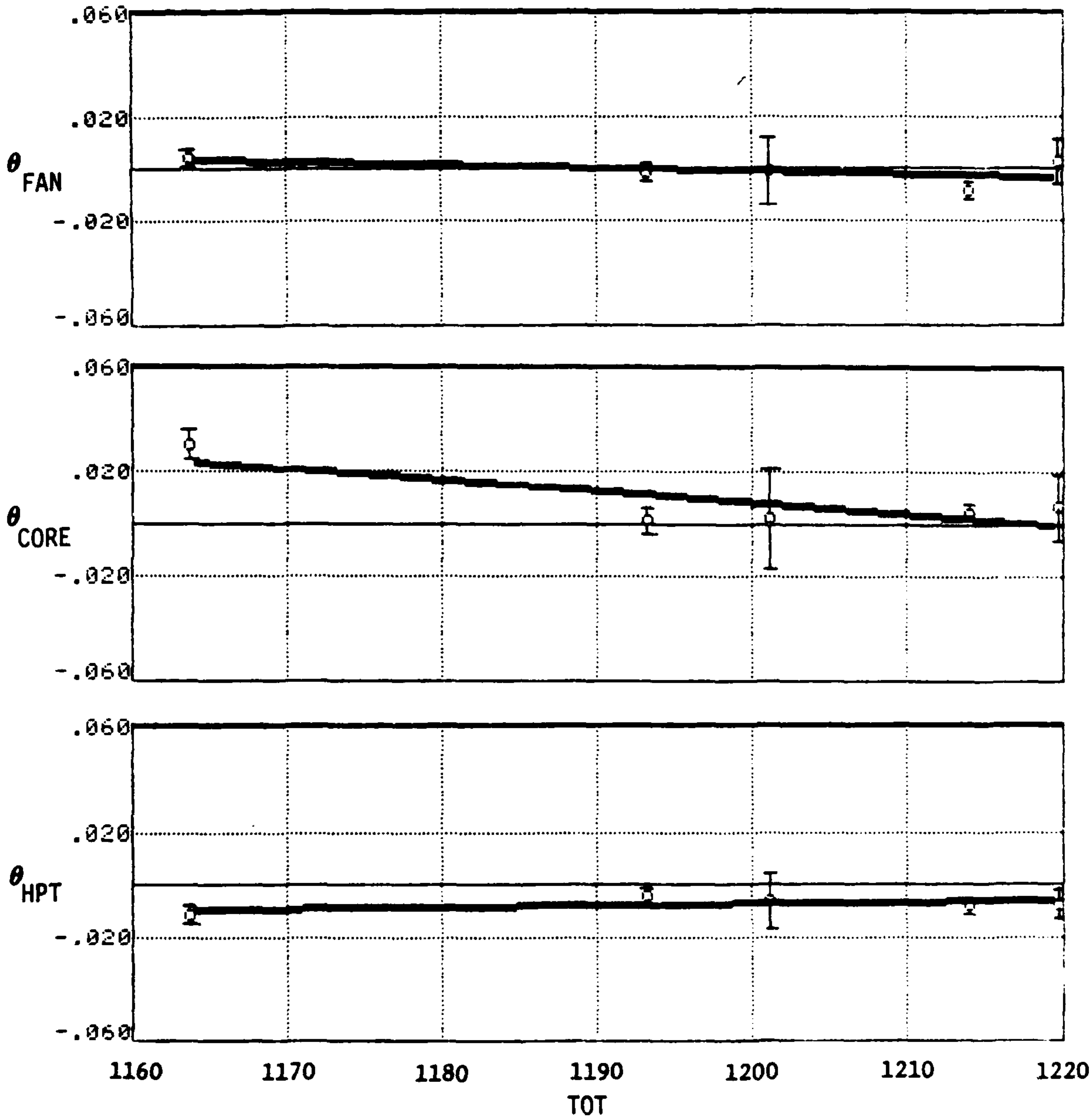


Figure 37. Short Term Trending Results
Engine S/N 801

misinterpreted. While they do indicate that the algorithm has not given unreasonable results, they do not confirm that the algorithm will indeed be responsive to the major maintenance actions that should cause easily discernable discontinuities in the short term trends.

SECTION V

ASSESSMENT OF SCT'S PROTOTYPE MAINTENANCE INFORMATION MANAGEMENT SYSTEM (MIMS)

A secondary objective of the Advanced Trend Analysis Program was to assess the usefulness of SCT's prototype Maintenance Information Management System (MIMS) as an engine maintenance/management tool. The EDS Flight Evaluation at Langley AFB was to have provided a suitable environment for USAF maintenance personnel to use and evaluate the prototype MIMS. Like the assessment of SCT's gas path analysis algorithm, the results of the MIMS assessment are inconclusive. The results are inconclusive because the USAF maintenance personnel at Langley did not use the prototype MIMS. This lack of use of the MIMS by the maintenance personnel was not the result of any gross deficiencies in the system but rather a product of the environment in which it was to have been evaluated. The following paragraphs briefly describe the MIMS and discuss the reasons for these inconclusive results.

1. <u>MIMS DESCRIPTION</u> - SCT's prototype MIMS is a software/hardware system designed to process and display engine maintenance and diagnostic data. This maintenance and diagnostic data includes the standard AFM 66-1 Maintenance Data Collection System data products, discussed in Section II.2, and ground/in-flight engine data automatically recorded by an engine monitoring/diagnostic system. The system software includes routines to rank/sort data, plot data, and list data within the constraints of user specified data attributes. The system hardware consists of both local, on-site equipment and a remotely located central computer. The on-site equipment includes a Hewlett-Packard 2648A Graphics Terminal, a Hewlett-Packard Graphics Printer, for obtaining hardcopy data products, and a telephone MODEM to communicate with the remotely located central computer. The central computer is a PDP 11/34 located at SCT's home location in Palo Alto, Ca. A more complete discussion of the MIMS and its capabilities can be found in SCT's Turbine Engine Fault Detection and Isolation (TEFDI) Program Final Report scheduled for release in early 1982.

2. <u>DISCUSSION OF RESULTS</u> - The results of the prototype MIMS evaluation are inconclusive. This is because the USAF maintenance personnel at Langley AFB did not use the system. As mentioned previously, this lack of use was not the result of any gross deficiencies in the system. On the contrary, during the MIMS training sessions held in late 1980, the USAF personnel were impressed with the flexibility and overall capabilities of the system. For reasons beyond the control of those responsible for the MIMS evaluation, it simply was not practical for the USAF maintenance personnel to use the MIMS. These reasons were as follows:

1) the location of the MIMS at Langley,

2) the relative size of the MIMS database, and

3) the timeliness of the MIMS data.

The MIMS was located in the MCAIR EDS office at Langley. It should have been located in the Comprehensive Engine Management Branch (CEMB) office. In the CEMB office, it would have been more accessible to the personnel who needed

to use it. The size of the MIMS data base was relatively small. Only the 11 EDS engines were in the data base. The CEMB personnel are responsible for all engines at Langley, including the approximately 150 F100 engines. The data available on the MIMS was not timely enough to be of practical use. The data ranged in age from several weeks to several months old. A study conducted by SCT showed that some of the data displayed by systems like the MIMS needs to be updated as frequently as every other day to be of practical use. Again, this untimeliness of the data was not the fault of the MIMS. The structure of the EDS Flight Evaluation and the groundrules under which the prototype MIMS demonstration was conducted made more frequent updating of the MIMS database impossible.

SECTION VI

SUMMARY AND CONCLUSIONS

The interfaces, parameter data, and data link information that were necessary to ensure accurate data transfer from the EDS Program at Langley AFB to the Computer Center at WPAFB were developed. The successful transfer and storage of data was accomplished. No definite conclusions were reached about SCT's gas path algorithm or prototype MIMS. The usefulness of SCT's algorithm was neither proven or disproven. The quantity and quality of the data acquired was not sufficient to adequately critique the algorithm. Additional data is required. However, the EDS Flight Evaluation at Langley has been terminated. The algorithm developed by SCT appears to offer significant improvement relative to other approaches and warrants further development and evaluation.

The following specific conclusions can be drawn from this program:

1.) Detailed studies of aircraft mission profiles and trending data acquisition "windows" are required early in the diagnostic system design phase to ensure acquisition rates sufficient for trending analyses.

2.) Easy modification of trending "windows",e.g. PLA limits and stability times, should be incorporated into diagnostic system logic.

3.) Ideal engine stability times, considered by some to be critical for successful gas turbine engine health trending, are not practically attainable for engines in tactical aircraft like the F100 in the F-15. A balance must be reached between adequate trending data acquisition rates and acceptable engine stability. The ramifications of this conclusion on the type of algorithm required to trend this data are obvious. Those algorithms that can handle this reduced stability data, like SCT's algorithm theoretically can, have a distinct advantage over those algorithms that require ultra-stable data.

4.) An automatic takeoff record appears to be an excellent way to supplement in-flight trending data. The data is clearly not as stable as the in-flight data but there are some indications that it is more repeatable.

5.) A MIMS-type system must be easily accessible and updated daily to be useful to base maintenance personnel.

SECTION VII

RECOMMENDATIONS

Gas turbine engine health trending holds the potential for increased efficiency in both diagnostic and prognostic engine maintenance. Accurate fault detection and isolation to the module level can result in reduced engine/aircraft downtime and increased numbers of ready engine spares. Dependable forcasting of engine/module deterioration trends can result in improved engine spare parts requirements projections and better overall management of engine assets. However, to fully realize this potential, an engine diagnostic/monitoring system to automatically record the trending must be adequately developed. This data must be acquired at a sufficiently high rate and with an acceptable level of stability to allow trending to be accomplished. In addition, a system to display and disseminate the trending results must also be adequately developed. Therefore, it is recommended that the USAF:

1.) Continue the development of airborne engine diagnostic/monitoring systems, like the F-15/F100 EDS, that will, among other functions, automatically record engine trending data.

2.) Continue development of maintenance information management systems to disseminate the data recorded by these airborne systems, including trending results, to cognizant personnel at the base, depot, and command level.

Along with the above, the following specific recommendations are made as a result of the Advanced Trend Analysis Program:

1.) Testing and evaluation of SCT's gas path analysis algorithm and prototype MIMS should be continued.

2.) An automatic takeoff trending record should be included in future tactical weapon system engine diagnostic/monitoring systems.

3.) Future test programs of systems like the F-15/F100 EDS should include a well defined effort to process, analyze, and display trending data as it is acquired. In this way, the stability requirements of the trending record data windows could be adjusted sooner in the program so that an adequate data acquisition rate could be experienced over a longer period of time.

REFERENCES

1. F100 Engine Diagnostic System (EDS) Flight Evaluation Plan, CDRL 1-00P, MDC A5566, 21 December 1979.

2. F100 Engine Diagnostic System (EDS) Final Technical Report, MDC A7042, 24 April 1981.

3. F100 Engine Diagnostic System (EDS) Final Technical Report, MDC A7042, Revision A, 30 September 1981.

APPENDIX A

This appendix contains detailed information about critical EDS measured parameters. Tables A-1 through A-16 contain information on the critical gas path parameters. Table A-17 contains information on the critical non-gas path parameters.

TABLE A-1. GAS PATH PARAMETER DETAILED INFORMATION

PARAMETER: Aircraft Altitude (H)*

UNITS: Feet (Ft)

SENSOR TYPE: Strain Gage Transducer

SENSOR RANGE: 0 to 80,000 ft

ACCURACY: $\pm$.2% F.S./0 to 80,000 ft

* NOTE: From Aircraft Air Data Computer (ADC)

TABLE A-2. GAS PATH PARAMETER DETAILED INFORMATION

PARAMETER: Aircraft Mach Number (MO)*

UNITS: Non-Dimensional

RANGE: 0.0 to 2.6

ACCURACY: $\pm$.02/0.0 to 2.6

* NOTE: Derived from Aircraft ADC Freestream Static Pressure (PS), Indicated Airspeed (VI), and Freestream Dynamic Pressure (QC)

TABLE A-3. GAS PATH PARAMETER DETAILED INFORMATION

PARAMETER: Engine Inlet Temperature (TT2)

UNITS: Degrees Centigrade (°C)

SENSOR TYPE: Chromel - Alumel Thermocouple (T/C)

SENSOR RANGE: -54°C to 250°C

COMPENSATION: Cold Junction Reference

CONVERSION TO ENGINEERING UNITS: Per NBS T/C Monogram 125, Cold Junction Relative

SENSOR ACCURACY: ±2.2°C

INTERCONNECT NOISE: ±2.2°C

EMUX ACCURACY: ±1.52°C

DPU/DDU ACCURACY: ±1°C

SYSTEM ACCURACY: 3.60°C

TABLE A-4. GAS PATH PARAMETER DETAILED INFORMATION

PARAMETER: Engine Inlet Pressure (PT2)*

UNITS: PSIA

RANGE: 1 to 38 PSIA

ACCURACY: ±0.19 PSIA/8.5 to 18.8 PSIA

* NOTE: Calculated From Aircraft ADC Freestream Static Pressure (PS), Derived Mach Number (MO), and Measured Low Spool Rotor Speed (N1) and Engine Inlet Temperature (TT2).

TABLE A-5. GAS PATH PARAMETER DETAILED INFORMATION

PARAMETER: Low Spool Rotor Speed (N1)

UNITS: Revolutions Per Minute (RPM)

SENSOR TYPE: Magnetic

SENSOR RANGE: 3000 to 15000 RPM

COMPENSATION: None Required

SENSOR ACCURACY: ±.2% Pt/3000 to 12000 RPM

EMUX ACCURACY: ±.16% Pt

DPU/DDU ACCURACY: ±.1% Pt

SYSTEM ACCURACY: ±.28% Pt

TABLE A-6. GAS PATH PARAMETER DETAILED INFORMATION

PARAMETER: High Spool Rotor Speed (N2)

UNITS: Revolutions Per Minute (RPM)

SENSOR TYPE: Magnetic

SENSOR RANGE: 1290 to 17745 RPM

COMPENSATION: None Required

SENSOR ACCURACY: $\pm$.2% Pt/6000 to 15000 RPM

EMUX ACCURACY: $\pm$.08% Pt

DPU/DDU ACCURACY: $\pm$.1% Pt

SYSTEM ACCURACY: $\pm$.24 % Pt

TABLE A-7. GAS PATH PARAMETER DETAILED INFORMATION

PARAMETER: Fan Exit Duct Temperature (TT2.5)

UNITS: Degrees Centrigrade (°C)

SENSOR TYPE: Chromel-Alumel Thermocouple (T/C)

SENSOR RANGE: -54°C to 350°C

COMPENSATION: Cold Junction Reference

CONVERSION TO ENGINEERING UNITS: Per NBS T/C Monogram 125, Cold Junction Relative

SENSOR ACCURACY: ±2.0°C

INTERCONNECT NOISE: ±2.2°C

EMUX ACCURACY: ±2.9°C

DPU/DDU ACCURACY: ±1°C

SYSTEM ACCURACY: ±4.27°C

TABLE A-8. GAS PATH PARAMETER DETAILED INFORMATION

PARAMETER: Fan Exit Duct Pressure (PT2.5)

UNITS: PSIA

SENSOR TYPE: Strain Gage Pressure Transducer

SENSOR RANGE: 0 to 100 PSIA

COMPENSATION: Third Order Temperature Compensation

SENSOR ACCURACY: $\pm$.2% F.S./17 to 60 PSIA

EMUX ACCURACY: $\pm$.26% F.S.

DPU/DDU ACCURACY: $\pm$.2% F.S.

SYSTEM ACCURACY: $\pm$.39% F.S.

TABLE A-9. GAS PATH PARAMETER DETAILED INFORMATION

PARAMETER: Compressor Discharge Static Temperature (TS3)

UNITS: Degrees Centigrade (°C)

SENSOR TYPE: Chromel-Alumel Thermocouple (T/C)

SENSOR RANGE: -54°C to 685°C

COMPENSATION: Cold Junction Reference

CONVERSION TO ENGINEERING UNITS: Per NBS T/C Monogram 125, *Cold Junction Relative*

SENSOR ACCURACY: ±3.0°C/200 to 600°C

INTERCONNECT NOISE: ±2.2°C

EMUX ACCURACY: ±2.9°C

DPU/DDU ACCURACY: ±1°C

SYSTEM ACCURACY: ±4.82°C

TABLE A-10. GAS PATH PARAMETER DETAILED INFORMATION

PARAMETER:	Engine Fuel Flow (WFT)
UNITS:	Pounds Per Hour (PPH)
SENSOR TYPE:	Turbine Flowmeter
SENSOR RANGE:	0-100,000 PPH
COMPENSATION:	Reference Signal Used to Account For Variations in 400 Hz Excitation Voltage
SENSOR ACCURACY:	±150 PPH/2400 to 13,400 PPH (at 400 Hz)*
DPU/DDU ACCURACY:	±33 PPH
SYSTEM ACCURACY:	±154 PPH

TABLE A-11. GAS PATH PARAMETER DETAILED INFORMATION

PARAMETER: Engine Burner Pressure (PB)

UNITS: PSIA

SENSOR TYPE: Strain Gage Pressure Transducer

SENSOR RANGE: 0 to 600 PSIA

COMPENSATION: Third Order Temperature Correction

SENSOR ACCURACY: $\pm$.2% F.S./100 to 470 PSIA

EMUX ACCURACY: $\pm$.26% F.S.

DPU/DDU ACCURACY: $\pm$.2% F.S.

SYSTEM ACCURACY: $\pm$.38% F.S.

TABLE A-12. GAS PATH PARAMETER DETAILED INFORMATION

PARAMETER: Fan Turbine Inlet Temperature, Average and Individual (FTITAVG and FTIT1-FTIT7)

UNITS: Degrees Centigrade (°C)

SENSOR TYPE: Chromel-Alumel Thermocouple (T/C)

SENSOR RANGE: -54°C to 1200°C

COMPENSATION: Cold Junction Reference

CONVERSION TO ENGINEERING UNITS: Per NBS T/C Monogram 125, Cold Junction Relative

SENSOR ACCURACY: ±7°C/0 to 1100°C

INTERCONNECT NOISE: ±2.2°C

EMUX ACCURACY: ±2.9°C

DPU/DDU ACCURACY: ±1°C

SYSTEM ACCURACY: ±7.95°C

TABLE A-13. GAS PATH PARAMETER DETAILED INFORMATION

PARAMETER: Augmentor Inlet Pressure (PT6)

UNITS: PSIA

SENSOR TYPE: Strain Gage Pressure Transducer

SENSOR RANGE: 0 to 100 PSIA

COMPENSATION: Third Order Temperature Correction

SENSOR ACCURACY: ±.2% F.S./16-65 PSIA

EMUX ACCURACY: ±.26% F.S.

DPU/DDU ACCURACY: ±.2% F.S.

SYSTEM ACCURACY: ±.38% F.S.

TABLE A-14. GAS PATH PARAMETER DETAILED INFORMATION

PARAMETER: Exhaust Nozzle Throat Area (AJ)

UNITS: Square Feet (Ft^2)

SENSOR TYPE: Synchro Transmitter

SENSOR RANGE: 2.71 to 6.40 Ft^2

COMPENSATION: AJ Reference Signal Used to Account for Frequency Variations in 400 Hz Excitation Voltage

SENSOR ACCURACY: $\pm$.054 Ft^2/2.75 to 6.4 Ft^2

EMUX ACCURACY: $\pm$.007 Ft^2

DPU/DDU ACCURACY: $\pm$.05 Ft^2

SYSTEM ACCURACY: $\pm$.074 Ft^2

TABLE A-15. GAS PATH PARAMETER DETAILED INFORMATION

PARAMETER: Rear Compressor Variable Vane Angle (RCVV)

UNITS: Degrees (mechanical)

SENSOR TYPE: Synchro transmitter

SENSOR RANGE: -44° to 4°

COMPENSATION: RCVV Reference Signal Used to Account for Frequency Variations in 400 Hz Excitation Voltage

SENSOR ACCURACY: ±.21°/-40° to 4°

EMUX ACCURACY: ±.6°

DPU/DDU ACCURACY: ±.25°

SYSTEM ACCURACY: ±.68°

TABLE A-16. GAS PATH PARAMETER DETAILED INFORMATION

PARAMETER: Power Lever Angle (PLA)

UNITS: Degrees (mechanical)

SENSOR TYPE: Synchro Transmitter

SENSOR RANGE: 0° to 130°

COMPENSATION: PLA Reference Signal Used to Account for Frequency Variations in 400 Hz Excitation Voltage

SENSOR ACCURACY: ±.167°

EMUX ACCURACY: ±.45°

DPU/DDU ACCURACY: ±.14°

SYSTEM ACCURACY: ±.5°

TABLE A-17. GAS PATH PARAMETER DETAILED INFORMATION

PARAMETER	SENSOR RANGE	SYSTEM ACCURACY
VIBRATIONS	.25 to 5 Mil	±9.05% F.S.
MOT	-54 to 225°C	±4.92°C
MOP	0 to 100 PSID	±3.53 PSID
MPB	0 to 25 PSIA	±4.08% F.S.
PSCV4	0 to 100 PSIA	±4.08% F.S.
TFO	-54 to 150°C	±4.91°C
PFO	0 to 100 PSIA	±4.08% F.S.
PF1	0 to 200 PSIA	±4.08% F.S.
PF2	0 to 1000 PSIA	±4.08% F.S.
PF1A	0 to 1000 PSIA	±4.08% F.S.

APPENDIX B

This appendix contains detailed logs of all the data transmitted to WPAFB as part of the Advanced Trend Analysis Program. Tables B-1 through B-16 are logs for EDS Data Transmittal Numbers 1 through 16 respectively.

TABLE B-1. EDS DATA TRANSMITTAL LOG

Number 1; 16 April Through 15 May 1980

ENGINE S/N	DATE	A/C TAIL NO.	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD	COMMENT
680160	14 May	74-103	401	X		
680330	19 April	74-108	627	X		Altitude Estimated From PS; Module Serial Numbers Unknown
680415	14 May	74-108	416	X		Module Serial Numbers Unknown
680470	18 April	74-107	657	X		Altitude Estimated From PS
	19 April	74-107	639	X		Same as Above
	20 April	74-107	643	X		
	20 April	74-107	656	X		
	6 May	74-107	GND	X		
	7 May	74-107	401	X		
680528	14 May	74-108	416	X		TT2, TS3, TT2.5 Bad

TABLE B-1 (Concluded). EDS DATA TRANSMITTAL LOG
Number 1; 16 April Through 15 May 1980

ENGINE S/N	DATE	A/C TAIL NO.	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD	COMMENT
680639	1 May	74-105	420		X	TT2 Bad
	5 May	74-105	401	X	X	Trend Record Taken Pre-Flight
	8 May	74-105	GND	X		
	9 May	74-105	413	X		MO Bad
	13 May	74-105	415	X		MO, TT2 Bad
680694	21 April	74-103	822	X		FTIT4 Bad
	29 April	74-103	405	X		TT2 Bad
	14 May	74-103	401	X		
680722	5 May	74-105	401		X	MO Bad
	8 May	74-105	GND	X		TT2 Bad
680801	20 April	74-107	643	X		
	6 May	74-107	GND	X		

TABLE B-2. EDS DATA TRANSMITTAL LOG

Number 2; 16 May Through 15 June 1980

ENGINE S/N	DATE	A/C TAIL NO.	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD	COMMENT
680160	16 May	74-103	406	X		
	19 May	74-103	401	X		
	30 May	74-103	999	X		Sortie Number Unknown
680639	23 May	74-105	407	X		TS3 Bad; MO Estimated From Temperature Ratio
	27 May	74-105	407	X		TT2.5 Bad; MO Estimated From Temperature Ratio
			410	X		TS3 Bad; MO Estimated From Temperature Ratio
	30 May	74-105	401	X	X	Same As Above
	10 June	74-105	GND	X		
680694	16 May	74-103	406	X		TT2.5 Bad
	19 May	74-103	401	X		
	30 May	74-103	999	X		Sortie Number Unknown
680722	21 May	74-105	418	X		MO Estimated From Temperature Ratio
	27 May	74-105	410	X		Same As Above
	30 May	74-105	401	X	X	Same As Above

TABLE B-3. EDS DATA TRANSMITTAL LOG

Number 3; 16 June Through 15 July 1980

ENGINE S/N	DATE	A/C TAIL NO.	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD	COMMENT
680311	30 June	74-099	409	X		WFT Failed
	2 July	74-099	412	X		WFT Failed
680330	11 July	74-103	410	X		
	15 July	74-103	401	X		RCVV Failed
680470	16 June	74-107	E1	X	X	Recorded At Eglin AFB
	10 July	74-107	413	X		
	14 July	74-107	407	X		WFT, PT6 Suspect
680639	16 June	74-105	E3	X		MO, PT2 Bad; TS3 Failed; Recorded at Eglin
680694	11 July	74-103	410	X		TT2.5 Bad; FTIT5 Failed
680722	16 June	74-105	E3	X		MO, PT2 Bad; Recorded At Eglin
680801	16 June	74-107	E1		X	Recorded At Eglin

TABLE B-4. EDS DATA TRANSMITTAL LOG

Number 4; 16 July Through 7 August 190

ENGINE S/N	A/C TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD	COMMENT
680160	74099	6 Aug	403			Bad EMUX; No Event Data
680311	Unin.	5 Aug	G/R #1			
			G/R #2			
680330	74103	16 July	G/R			
		17 July	406			
			412			
		21 July	403			
			410			
			418			
		23 July	405	X		TT2.5 Failed
			411			
		24 July	407			
			412	X		TT2.5 Failed
			413			
		25 July	406			
		30 July	704			
		31 July	709		X	TT2.5 Failed
			720	X	X	TT2.5 Failed
			727	X		

TABLE B-4 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE S/N	A/C TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD	COMMENT
680330	74103	1 Aug	701	X		TT2.5 Failed
			706			
			718			
		6 Aug	405			
			410	X	X	TT2.5 Failed
			413	X	X	TT2.5 Failed
		7 Aug	401			
			406			
			411			
680470	74107	16 July	411			
		18 July	G/R			
		21 July	414	X		Bad Data
		22 July	403			
			414	X		
		29 July	404			
		30 July	247			
		31 July	213	X		
			228			
			242	X	X	Perf. Rcd. In A/B
			255			
		1 Aug	202			
			218		X	
		7 Aug	402			
			407			
			412			

TABLE B-4 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE S/N	A/C TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD	COMMENT
680528	74099	21 July	405			
			412			
		25 July	408			
		29 July	220			
		30 July	201			
			214	X		TT2/WFT Failed
		1 Aug	G/R			
680639	74105	21 July	401	X		
		31 July	706			
			715	X		
		1 Aug	708			
680694	74103	16 July	G/R			
		17 July	406			
			412			
		21 July	403			
			410	X		FTIT5 Failed
			418			
		23 July	405	X		FTIT5 Failed
			411			
			413			

TABLE B-4 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE S/N	A/C TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD	COMMENT
680694	74103	24 July	407			
			412	X		FTIT5 Failed
		30 July	704			
		31 July	709		X	FTIT5 Failed
			720		X	FTIT5 Failed
			727	X		FTIT5 Failed
		1 Aug	701	X		TT2.5/FTIT5 Failed
			706			
			718			
		6 Aug	405			
			410	X	X	
			413	X	X	Perf. Rcd. In A/B
		7 Aug	401			
			406			
			411	X		
680722	74105	21 July	401	X	X	Trend OK; Perf. Rcd. MO/PT2 Bad
		31 July	706			
			715			Bad EMUX
		1 Aug	708			Bad EMUX

TABLE B-4 (Concluded). EDS DATA TRANSMITTAL LOG

ENGINE S/N	A/C TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECROD	COMMENT
680801	74107	16 July	411			
		18 July	G/R			
		21 July	414			
		22 July	403			
			414			
		29 July	204			
		30 July	247			
		31 July	213	X		TT2.5 Failed
			228			
			242		X	TT2.5 Failed, PLA In A/B
			255			
		1 Aug	202			
			218		X	TT2.5 Failed
		7 Aug	402			
			407			
			412			
680907	74099	21 July	405			
			412			
		25 July	408			
		30 July	201	X		WFT Failed
			214	X		WFT Failed
		1 Aug	G/R			
		6 Aug	403	X		

TABLE B-5. EDS DATA TRANSMITTAL LOG

Number 5; 8 August Through 15 September 1980

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680160	74099	12 Aug	G/R		
		14 Aug	G/R		
		19 Aug	G/R	X	
		20 Aug	404	X	
		2 Sept	404		
		6 Sept	881		X
		9 Sept	G/R #1 G/R #2 G/R #3 G/R #4 G/R #5		
680311	74105	9 Aug	401		
		11 Aug	402 415	 X	
		12 Aug	411		
		13 Aug	402		
		15 Aug	409	X	
		2 Sept	401		

TABLE B-5 (Continued). EDS DATA TRANSMITTAL LOG

Number 5; 8 August Through 15 September 1980

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680311	74108	9 Sept	218		
↓	↓	11 Sept	971		
680330	74103	8 Aug	407	X	
		↓	413		
		9 Aug	402		
		11 Aug	401		
			408	X	
		↓	414	X	X
		13 Aug	412		X
		14 Aug	410		
		20 Aug	403		X
		↓	413	X	
		21 Aug	405		X
		5 Sept	412	X	
		9 Sept	205	X	
		10 Sept	105		X
		↓	244		
		11 Sept	964		
↓	↓	12 Sept	916		

TABLE B-5 (Continued). EDS DATA TRANSMITTAL LOG

Number 5; 8 August Through 15 September 1980

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680415	74108	11 Aug	417		
		12 Aug	410		
		14 Aug	G/R 405		
		19 Aug	413		
		22 Aug	402		
		28 Aug	405 410		
		2 Sept	G/R		
		5 Sept	401 407 415		
		9 Sept	218		
		11 Sept	971		
680470	74107	11 Aug	G/R 403		
680528	74107	13 Aug	401		
		14 Aug	412		
		19 Aug	401 408	X	

TABLE B-5 (Continued). EDS DATA TRANSMITTAL LOG

Number 5; 8 August Through 15 September 1980

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680528	74107	28 Aug	406		
			411		
		12 Sept	914		X
680639	74105	9 Aug	401		
		11 Aug	402		
			415	X	
		12 Aug	401		
			411		
		13 Aug	402		
		15 Aug	409	X	
		2 Sept	401		
680694	74103	8 Aug	407	X	
			413		
		9 Aug	402		
		11 Aug	401		
			408	X	
			414		X
		13 Aug	412		X
		14 Aug	410		
		20 Aug	403		X
			413	X	

TABLE B-5 (Continued). EDS DATA TRANSMITTAL LOG

Number 5; 8 August Through 15 September 1980

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680694	74103	21 Aug	405		X
		5 Sept	412	X	
		9 Sept	205	X	
		10 Sept	105	X	X
			244		X
		11 Sept	964		
		12 Sept	916		
680722	UNIN	9 Aug	G/R		
		13 Aug	G/R		
	74108	5 Sept	401		
			407		
			415	X	X
	UNIN	11 Sept	G/R #1		
			G/R #2		
380801	74107	11 Aug	G/R		
			403		
		13 Aug	401		
		14 Aug	412		

TABLE B-5 (Concluded). EDS DATA TRANSMITTAL LOG

Number 5; 8 August Through 15 September 1980

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680801	74107	19 Aug	401		
			408	X	
		28 Aug	406		
			411		
		12 Sept	914		X
680907	74099	12 Aug	G/R	X	
		14 Aug	G/R		
		19 Aug	G/R		
		20 Aug	404		
		2 Sept	404		
		6 Sept	881	X	X
		9 Sept	G/R #1		
			G/R #2		
			G/R #3		
			G/R #4		
		12 Sept	402		
			922		X

TABLE B-6. EDS DATA TRANSMITTAL LOG

Number 6; 16 September Through 31 October 1980

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680160	74105	24 Sept	404		
		2 Oct	406		
			412		
		6 Oct	408		
		8 Oct	401	X	
			407	X	
			412	X	
		10 Oct	405	X	
			412		
		17 Oct	712	X	X
		21 Oct	406		
			413	X	
		23 Oct	404	X	
			410	X	
		27 Oct	405		
		29 Oct	404		
680311	74108	17 Sept	404		
			413	X	
		19 Sept	401	X	
			407	X	
		1 Oct	409		
			414		

TABLE B-6 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680311	74108	3 Oct	408	X	
		6 Oct	401		
		7 Oct	415		
		16 Oct	G/R		
680330	74103	17 Sept	405		
			407		
			410	X	
		19 Sept	406		
			409	X	
		22 Sept	401		X
			408	X	
			411	X	
		24 Sept	401		
			407		
			410	X	
		2 Oct	404		
			411	X	X
			416		
		3 Oct	G/R		
		7 Oct	406		
			412		
	74107	22 Oct	404		
			409	X	
		23 Oct	406	X	

TABLE B-6 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680330	74107	27 Oct	8	X	
			414	X	X
		29 Oct	402		
			406	X	
		30 Oct	409		
		31 Oct	402		
680415	74108	17 Sept	409		
			404		
			413	X	
		19 Sept	401		
			407		
		1 Oct	409		
			414		
		3 Oct	408		
		6 Oct	401		
		9 Oct	415		
		16 Oct	G/R		
680470	74099	22 Oct	G/R 1		
			G/R 2		
			G/R 3		
		24 Oct	G/R 1		
			G/R 2		

TABLE B-6 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680470	74099	28 Oct	G/R		
			401		
		30 Oct	404		
680528	74107	19 Sept	G/R 1		
			G/R 2		
			G/R 3		
		23 Sept	402	X	
			409	X	
			412	X	
		24 Sept	405		
			411		
		2 Oct	408		
		6 Oct	406	X	X
			412		
		7 Oct	405		
	74103	17 Oct	938		
		20 Oct	403		
680639	74105	24 Sept	404		
		2 Oct	406		
			412	X	
		6 Oct	408		

TABLE B-6 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680694	74103	3 Oct	G/R		
		7 Oct	406		
			412		
		8 Oct	410		
			414		
		9 Oct	408		
		15 Oct	206		
		16 Oct	236		
		17 Oct	938	X	
		20 Oct	403		
680722	74107	19 Sept	G/R 1		
			G/R 2		
			G/R 3		
		23 Sept	402	X	
			409	X	
			412	X	
		24 Sept	405		
			411		
		2 Oct	408		
		6 Oct	406		X
			412		X
		7 Oct	405		

TABLE B-6 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680722	74107	9 Oct	405	X	
		15 Oct	207		
		16 Oct	704		
		20 Oct	402	X	
			416		X
		22 Oct	404		
			409		
		23 Oct	406		
		27 Oct	8	X	
			414	X	X
		29 Oct	402		
			406	X	
		30 Oct	409		
		31 Oct	402		
680907	74099	18 Sept	405	X	
			410		
		1 Oct	415		
		3 Oct	407	X	
		6 Oct	403	X	
			416		X
		8 Oct	403		
			409		

TABLE B-6 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680639	74105	8 Oct	401	X	
			407		X
			412	X	
		10 Oct	405	X	
			412		
		17 Oct	712	X	X
		21 Oct	406		
			413	X	
		23 Oct	404	X	
			410	X	
		27 Oct	405	X	
		29 Oct	404		
680694	74103	17 Sept	405		
			407		
			410	X	
		19 Sept	406		
			409		
		22 Sept	401		
			408	X	
			411	X	
		24 Sept	401		
			407		
			410		
		2 Oct	404		
			411		
			416		

TABLE B-6 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680907	74099	10 Oct	409		
		15 Oct	213		
		16 Oct	211	X	
		17 Oct	901		
		20 Oct	G/R		
		22 Oct	G/R 1 G/R 2 G/R 3		
		24 Oct	G/R 1 G/R 2 G/R 3		
		28 Oct	G/R 401		
		30 Oct	404		

TABLE B-7. EDS DATA TRANSMITTAL LOG

Number 7; 1 November Through 11 December 1980

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
68160	74105	3 Nov	408		
			414	X	X
		6 Nov	205	X	
		13 Nov	401		
			414		
680311	74108	3 Nov	407		X
		6 Nov	203	X	
			218	X	
			226		
			243		
		8 Nov	946	X	
		13 Nov	415	X	X
		14 Nov	406	X	
		18 Nov	406	X	
		20 Nov	ORI		
		1 Dec	404		

TABLE B-7 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680311	74108	2 Dec	418		
		5 Dec	406		
		8 Dec	401		
		9 Dec	404	X	X
			818		
		10 Dec	806		
		11 Dec	?		
680330	74107	6 Nov	204		
		8 Nov	913		
			954	X	X
		9 Nov	?		
		12 Nov	413		X
		20 Nov	G/R		
		21 Nov	243		
		22 Nov	ORI		X
		23 Nov	ORI		

TABLE B-7 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680330	74107	1 Dec	406		X
		3 Dec	402		X
			414		
		5 Dec	414		
		8 Dec	808		
		10 Dec	?	X	
680415	74108	3 Nov	407		X
		7 Nov	203	X	
			218	X	
			226		
			243		
		8 Nov	946	X	
		13 Nov	415	X	X
		14 Nov	406	X	X
		18 Nov	406	X	
		20 Nov	ORI		
		1 Dec	404		
		2 Dec	418		

TABLE B-7 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680415	74108	5 Dec	406		
		8 Dec	401		
		9 Dec	404 818	X	X
		10 Dec	806		
		11 Dec	?		
680470	74099	3 Nov	881	X	
		4 Nov	402 408		
		14 Nov	408	X	
		17 Nov	403 409	X	
		20 Nov	ORI		
		25 Nov	ORI	X	
		2 Dec	405		
		4 Dec	407		
		8 Dec	404 412		

TABLE B-7 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680470	74099	9 Dec	407		
			814		
680528	74103	4 Nov	401	X	
	UNIN	8 Nov	G/R	X	
	74105	17 Nov	401		
			407		
		20 Nov	501		
		10 Dec	813		
680639	74105	3 Nov	414		X
		6 Nov	205	X	
		13 Nov	401		
			414		
		17 Nov	401		
			407	X	
		20 Nov	501		
		10 Dec	813		
680694	74013	4 Nov	401	X	
680722	74107	6 Nov	204		
		8 Nov	913	X	
			954	X	X

TABLE B-7 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680722	74107	9 Nov	?	X	
		12 Nov	413		X
		21 Nov	243		
		22 Nov	ORI		
		23 Nov	ORI		
		1 Dec	406		X
		3 Dec	402 414		X
		5 Dec	414		
		8 Dec	808		
680801	UNIN	12 Nov	G/R	X	
		13 Nov	G/R	X	
680907	74099	3 Nov	881	X	
		4 Nov	402 408		
		14 Nov	408	X	

TABLE B-7 (Concluded). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680907	74099	17 Nov	403 409	X	
		20 Nov	ORI		
		25 Nov	ORI	X	
		2 Dec	405		
		4 Dec	407		
		8 Dec	404 412		
		9 Dec	407 814		

TABLE B-8. EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680160	74107	29 Dec	415		
		8 Jan	417		
		26 Jan	415		
		28 Jan	G/R 403		
680311	74108	19 Dec	409		
680415	74108	19 Dec	409		
		6 Jan	403		
		8 Jan	409		
		21 Jan	883		
		22 Jan	418	X	
		27 Jan	405	X	
		28 Jan	407		
		30 Jan	404		

TABLE B-8 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680470	74099	17 Dec	407		
		19 Dec	413		
		22 Dec	408		
		29 Dec	402		
680528	74105	22 Dec	415		X
		8 Jan	415		
		22 Jan	419	X	
680639	74105	22 Dec	415		X
		8 Jan	415		
		22 Jan	419	X	
		28 Jan	408		
680801	74108	6 Jan	403		
		8 Jan	409		
		21 Jan	883		
		22 Jan	418	X	

TABLE B-8 (Concluded). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO. NO.	TREND RECORD	PERFORMANCE RECORD
680801	74108	27 Jan	405		
		28 Jan	407		
		30 Jan	404		
680907	74099	17 Dec	407		
		19 Dec	413		
		22 Dec	408		
		29 Dec	402		

TABLE B-9. EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680160	74107	9 Feb	423		
		11 Feb	414 809		X
		18 Feb	415		
		19 Feb	402		
		8 Mar	218		
		9 Mar	506 228		
		10 Mar	221 G/R		
680330	74107	9 Feb	423		
		11 Feb	414 809		X
		18 Feb	415		
		19 Feb	402		
		8 Mar	218 502		X

TABLE B-9 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680330	74107	9 Mar	506 228		
		10 Mar	221 G/R		
680415	74108	3 Feb	408		
		18 Feb	? ?		
		7 Mar	201 226		X
		8 Mar	219 238		
680470	74099	7 Mar	513		X
		8 Mar	225 516		
		9 Mar	507		
		10 Mar	235		X
		11 Mar	203		
680528	74105	12 Feb	413		
		17 Feb	404		

TABLE B-9 (Concluded). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORMANCE RECORD
680528	74105	18 Feb	414		
		8 Mar	214		
680639	74105	12 Feb	413		
		17 Feb	404		
		18 Feb	414		
		8 Mar	214 G/R		
680801	74108	3 Feb	408		
		18 Feb	? ?		
		7 Mar	201 226		X
		8 Mar	219 238		
680907	74099	7 Mar	513		
		8 Mar	225 516		
		9 Mar	507		
		10 Mar	235		
		11 Mar	203		

TABLE B-10. EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORM. RECORD	TAKE-OFF RECORD
680160	74107	17 March	G/R			
		18 March	413 419			
		19 March	402 410			
		24 March	G/R			
680330	74107	17 March	G/R			
		18 March	413 419			
		19 March	402 410			
		24 March	G/R			
680470	74099	16 March	408			X
		18 March	411			X
		23 March	420			X
		26 March	415			X

TABLE B-10 (Concluded). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORM. RECORD	TAKE-OFF RECORD
680528	74105	26 March	408			X
			412			X
			418			X
		30 March	418			X
		31 March	416			X
680694	74105	26 March	408			X
			412			X
			418			
		30 March	418		X	
		31 March	416			X
680907	74099	16 March	408			X
		18 March	411			X
		23 March	420			X
		26 March	415			X

TABLE B-11. EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORM. RECORD	TAKE-OFF RECORD
680160	74107	6 Apr	407			
680330	74107	6 Apr	407	X	X	
680415	74108	1 Apr	425			X
		2 Apr	408	X		X
			422	X	X	
		6 Apr	403			X
			412	X	X	X
			428	X	X	X
		7 Apr	414			X
680470	74099	2 Apr	405		X	X
		3 Apr	404		X	
		6 Apr	G/R			
			406		X	X
			413	X	X	X
			427		X	X
		7 Apr	409	X	X	
			419			X
			428	X		X
		8 Apr	404		X	X
			429	X	X	X

TABLE B-11 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORM. RECORD	TAKE-OFF RECORD
680470	74099	15 Apr	416		X	X
			881		X	X
680528	74105	6 Apr	415		X	X
		13 Apr	905			X
			915			X
		16 Apr	401			X
680694	74105	6 Apr	415		X	X
		13 Apr	905			X
			915	X		X
		16 Apr	401			X
680801	74108	1 Apr	425			X
		2 Apr	408	X	X	X
			422	X	X	
		6 Apr	403			X
			412	X	X	X
			428	X	X	X
		7 Apr	414			X

TABLE B-11 (Concluded). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORM. RECORD	TAKE-OFF RECORD
680907	74099	2 Apr	405		X	X
		3 Apr	404			
		6 Apr	G/R			
			406		X	X
			413	X		X
			427	X	X	X
		7 Apr	409		X	
			419			X
			428	X		X
		8 Apr	404		X	X
			429	X		X
		15 Apr	416	X		X
			881	X	X	X

TABLE B-12. EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORM. RECORD	TAKE-OFF RECORD
680160	74107	20 Apr	406			X
			421			X
		22 Apr	404			X
			412			X
			418	X	X	X
		23 Apr	404			X
			413		X	X
		27 Apr	GAB			
			401			X
		30 Apr	403	X	X	X
680330	74107	20 Apr	406	X	X	X
			421			X
		22 Apr	404			X
			412			X
			418	X	X	X
		23 Apr	404			X
			413		X	X
		27 Apr	GAB			
			401			X
		30 Apr	403	X	X	X

TABLE B-12 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORM. RECORD	TAKE-OFF RECORD
680415	74108	19 Apr	TDY 11	X	X	X
		21 Apr	416			X
		23 Apr	408	X	X	X
			420	X	X	X
		28 Apr	414		X	X
		29 Apr	401	X	X	X
680470	74099	16 Apr	410			X
		17 Apr	408		X	X
		27 Apr	402			X
		28 Apr	401			X
			411	X	X	X
		30 Apr	404	X	X	X
680528	74105	17 Apr	407	X	X	X
		20 Apr	401			
			417	X	X	X
		21 Apr	410	X	X	
			417			

TABLE B-12 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORM. RECORD	TAKE-OFF RECORD
680528	74105	22 Apr	401	X	X	
			409	X	X	
			415	X	X	
		23 Apr	401			X
			410	X	X	
			417	X	X	
680694	74105	17 Apr	407	X	X	X
		20 Apr	401			
			417	X	X	X
		21 Apr	410	X	X	
			417			
		22 Apr	401	X	X	
			409	X	X	
			415	X	X	
		23 Apr	401			X
			410	X	X	
			417	X	X	
680801	74108	19 Apr	TDY 11	X	X	X
		21 Apr	416		X	X
		23 Apr	408	X	X	X
			420	X	X	X

TABLE B-12 (Concluded). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORM. RECORD	TAKE-OFF RECORD
680801	74108	28 Apr	414		X	X
		29 Apr	401	X	X	X
680907	74099	16 Apr	410			X
		17 Apr	408		X	X
		27 Apr	402			X
		28 Apr	401			X
			411	X	X	X
		30 Apr	404	X	X	X

TABLE B-13. EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORM. RECORD	TAKE-OFF RECORD
680160	74107	6 May	402			X
		11 May	404			X
			411	X	X	X
			414			
		12 May	401			X
			412			
		13 May	G/R			
		14 May	405			
			409	X	X	X
680311	74105	12 May	402			X
		13 May	405		X	
			409	X	X	
		14 May	405	X	X	
			413	X	X	
680330	74107	6 May	402			X
		11 May	404			X
			411	X	X	X
			414			

TABLE B-13 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORM. RECORD	TAKE-OFF RECORD
680330	74107	12 May	401			X
		13 May	G/R			
			412		X	
		14 May	405	X	X	
			409		X	X
680415	74108	12 May	405			
			411	X		X
		13 May	404	X	X	X
			408	X	X	X
			412	X	X	X
		14 May	401	X	X	X
			406	X	X	X
			410	X	X	X
680470	74099	11 May	407	X		X
			412	X	X	X
		12 May	404		X	X
			413	X		X
		13 May	402	X	X	X
			406			X
			410	X	X	X

TABLE B-13 (Concluded). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORM. RECORD	TAKE-OFF RECORD
680528	74099	9 May	TDY2	X		X
680694	74099	9 May	TDY2	X		X
		12 May	402			
		13 May	405		X	
			409	X	X	
		14 May	403	X	X	
			405	X	X	
680801	74108	12 May	405			
			411	X		X
		13 May	404	X	X	X
			408	X	X	X
			412	X	X	X
		14 May	401	X	X	X
			406	X	X	X
			410	X	X	X
680907	74099	11 May	407	X		X
			412	X		X
		12 May	404			X
			413	X		X
		13 May	402	X		X
			406			X
			410	X	X	X

TABLE B-14. EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORM. RECORD	TAKE-OFF RECORD
680160	74107	18 May	401	X		X
			409	X		X
			?			X
680311	74105	16 May	G/R 1			
			G/R 2			
		18 May	?	X	X	
			404	X		
		21 May	401	X	X	X
			411			X
		26 May	401	X	X	X
			413			X
			423	X	X	X
680330	74107	18 May	401	X	X	X
			409	X	X	X
			?		X	X
680415	74108	28 May	417	X	X	X
		29 May	410	X	X	X

TABLE B-14 (Continued). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORM. RECORD	TAKE-OFF RECORD
680470	74099	21 May	?	X		X
			419	X	X	X
		26 May	407	X	X	
			428		X	
		27 May	G/R 1			
			G/R 2			
			G/R 3			
		28 May	G/R			
			429	X		X
		29 May	407			X
680528	74105	18 May	?	X	X	
			404	X		
		21 May	401	X	X	X
			411			X
		26 May	401	X	X	X
			413			X
			423	X	X	X

TABLE B-14 (Concluded). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORM. RECORD	TAKE-OFF RECORD
680694	74105	16 May	G/R 1	X		
			G/R 2	X		
680801	74108	28 May	417	X	X	X
		29 May	410		X	X
680907	74099	21 May	?	X		X
			419	X		X
		26 May	407	X	X	
			428	X	X	
		27 May	G/R 1			
			G/R 2			
		28 May	G/R			
			429	X		X
		29 May	407			X

TABLE B-15. EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORM. RECORD	TAKE-OFF RECORD
680311	74105	10 June	223			X
		11 June	G/R 1	X		
			G/R 2			
680415	74108	2 June	703	X	X	X
			708	X	X	X
		8 June	G/R	X		
		10 June	G/R 1	X		
			G/R 2	X		
			G/R 3			
			G/R 4	X		
			G/R 5			
		12 June	G/R			
680470	74099	3 June	707	X	X	X
			716		X	X
		4 June	710	X	X	X
		9 June	706		X	X
		10 June	719		X	X
680528	74105	10 June	223	X	X	X
		11 June	G/R 1			
			G/R 2			

TABLE B-15 (Concluded). EDS DATA TRANSMITTAL LOG

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORM. RECORD	TAKE-OFF RECORD
680801	74108	2 June	703	X	X	X
			708	X	X	X
		8 June	G/R			
		10 June	G/R 1			
			G/R 2			
			G/R 3			
			G/R 4			
			G/R 5			
		12 June	G/R			
680907	74099	3 June	707	X	X	X
			716			X
		4 June	710	X		X
		9 June	706			X
		10 June	719			X

TABLE B-16. EDS DATA TRANSMITTAL LOG

Numbers 16; 13 June Through 30 June 1981

ENGINE SERIAL NO.	AIRCRAFT TAIL NO.	DATE	SORTIE NO.	TREND RECORD	PERFORM. RECORD	TAKE-OFF RECORD
680160	74099	16 June	702			X
680415	74108	16 June	703	X	X	X
680801	74108	16 June	703	X	X	X
680907	74099	16 June	702			X

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5-8